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DECOMPOSITION OF FOREST LITTER AND THE CYCLE OF ELEMENTS IN AN OAK FOREST

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There are two distinct periods in the annual cycle of an oak forest. The first is the time of formation of the forest litter under the influence of autumn defoliation. In the oak forest of the Voronezh State Reservation, where we made our investigation, leaf-fall begins at the end of August and ends in early November.[1] The second period, which embraces the other months of the year, is the time when the fallen leaves decompose.

Long-term investigations showed that the mass of foliage forming in an oak forest every year does not change in relation to the age of the tree stand. Weather conditions in individual years have a much greater effect (2, 3, 4). Data on the amount of litter in a sedge-goutweed oak forest show essential differences in the mass of litter forming annually. This influence manifests itself differently in plot areas in oak stands of different ages (Table 1).

Depending on the fluctuations in the mass of litter, the amount of nutrient elements which return to the soil surface with the litter also changes. This can be illustrated by data for a 93- to 106-year old oak stand, where the difference in age has the least effect, and the observed fluctuations in the amount of litter are caused primarily by weather conditions (Table 2).

The alternation in the annual cycle of the litter formation and its subsequent decomposition determines the change in the mass of forest litter. The amount of litter in an oak forest is greatest at the beginning of spring and consists of undecomposed old litter and litter accumulated during the autumn and partly during the winter-spring season. The forest litter decomposes during the following spring-summer season and by the time autumn leaf-fall occurs the mass of litter reaches its lowest value. The change in the mass of litter from 1957-1958 can serve as an example. After autumn leaf-fall, supplemented by the spring leaf-fall of late oak, the total amount of forest litter was 13.2 metric tons/ha. Decomposition in summer reduced this amount at the beginning of the next leaf-fall to 9.7 metric tons/ha. The difference of 3.5 metric tons/ha corresponds approximately to the leaf-fall.

Both changes in the mass of litter and in the rate of its mineralization depend on weather conditions. Generally, however, the decomposition of litter corresponds more or less to the accumulation of litter, with unavoidable deviations in one or the other directions. For the sake of comparison we must mention that the amount of forest litter in pine stands in the same forest massive is 37-46 metric tons/ha.

Two layers can be distinguished in the composition of forest litter in an oak forest. The largest mass fluctuations occur in the upper layer, which consist of fallen leaves and is designated by the letter L. The weight of this layer was 5.3 metric tons/ha in the spring of 1958, while it decreased to 2.7 metric tons/ha, i. e., by 2.6 metric tons/ha, at the beginning of leaf-fall. Mass fluctuations in the second layer (or fermentation layer), which we will designate by the letter F, were smaller. This layer consists of almost completely decomposed leaves of a dark brown color, which are interwoven with the mycellia of fungi. The entire F layer weighed 7.9 metric tons/ha in spring, while before leaf-fall its weight became 6.9 metric tons/ha, i. e., its mass was reduced by 1.0 metric tons/ha.

As the mass of the layers of forest litters decreases, the content of ash elements in them increases because of the decomposition of organic compounds, primarily carbohydrates. We found an increase in the content of ash elements in the L layer from 5.2% to 6.5% from spring to autumn; the increase in the F layer was from 8.2% to 9.4%.

As compared to the fallen leaves (Table 3) the forest litter becomes poor in nitrogen, potassium, phosphorus, and magnesium and relatively rich in silica, aluminum, and iron, and slightly less in calcium as it decomposes. This is especially noticeable at the fermentation layer (F), where the decrease in potassium is most pronounced.

Additional patterns are revealed by the calculation of the total content of elements in the forest litter (in kg/ha) and its separate layers

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[1] There is also a leaf-fall in spring in stands containing late oak, which keeps its dry leaves until spring.

Table 1

Dynamics of litter fall in a sedge-goutweed oak forest on dark gray-brown sandy loam forest soils

Age of the stand	Years of observation, metric tons/ha												
	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960
12—24	2,8	3,5	4,3	4,6	3,3	3,7	4,2	3,7	4,1	3,4	4,2	3,8	3,2
48—60	3,3	4,1	4,0	4,1	3,7	4,1	4,9	3,8	4,7	4,3	3,9	4,1	3,5
93—106	3,1	2,8	4,0	4,9	4,3	4,6	5,5	4,4	5,3	4,6	4,4	4,0	4,0
130—142	—	3,8	4,9	4,2	4,2	3,9	5,4	4,8	5,1	3,4	4,7	5,1	3,6

Note: Comma represents decimal point.

Table 2

Amount of nitrogen and ash elements from the leaf-fall (leaves) in a 93- to 106- year old sedge-goutweed oak stand

Years litter collected	N	Si	Al+Fe	Ca	Mg	K	P	S
	kg/ha per year							
1948	32,9	18,6	3,8	57,0	8,9	21,0	4.9	4,8
1949	30,6	17,1	3,5	54,5	7,7	19,6	4,6	4,7
1950	42,8	22,1	4,6	72,5	10,4	25,8	6,1	6,0
1951	54,9	27,7	5,6	95,5	12,5	33,9	8,2	8,4
1952	46,3	22,2	5,1	74,7	10,7	25,6	6,2	6,1
1953	43,9	21,5	5,0	80,8	11,6	27,6	6,7	6,6
1954	54,2	27,5	5,8	95,6	13,4	33,3	7,9	7,7
1955	43,2	24,0	4,1	72,3	10,8	25,2	6,0	4,9
1956	48,6	26,2	4,8	81,0	12,1	28,2	6,7	6,7
1957	46,0	23,9	4,3	77,3	11.2	26,9	6.6	6,4
1958	43,2	24,0	4,1	72,3	10,8	25.2	6,0	4,9
1959	30,9	21,0	3,1	59,3	9,0	14,2	9,9	4,9
1960	37,5	25,5	3,7	72,0	10,9	17,2	11,9	6,0

Note: Comma represents decimal point.

(Table 4). Such a calculation shows that the total content of iron in the forest litter hardly changes during decomposition and the aluminum content decreases only slightly; the decrease in the amount of silicon is more pronounced. The improverishment of the litter is greatest

Table 3

Content of nitrogen and ash elements in fallen leaves and in the litter of an oak forest, 1958

Sampling time	Layers	N	Si	Al	Fe	Ca	Mg	K	P
		In % of substance dried at 100 °C							
	Litter	1,95	0,45	0,03	0,04	1,64	0,22	0,45	0,17
June	L	1,81	0,53	0,29	0,13	0,70	0,14	0,20	0,16
Same	F	0,64	0,81	0,45	0,20	1,88	0,21	0,11	0,09
July	L	1,70	0,55	0,32	0,16	1,62	0,16	0,17	0,14
Same	F	1,52	0,84	0,49	0,25	1,82	0,17	0.09	0,08
August	L	1,63	0,57	0,37	0,18	1,41	0,14	0,14	0,13
Same	F	1,46	0,87	0,52	0,27	0,90	0,17	0,07	0,07

Note: Comma represents decimal point.

Table 4

Change in the content of nitrogen and ash elements in the litter of an oak forest

Sampling time	Layers	N	Si	Al	Fe	Ca	Mg	K	P
		Content in kg/ha							
June	L	96,3	28,2	15,4	6,9	90,4	7,4	10,6	8,5
	F	129,9	64,2	35,6	15,8	148,9	16,6	8,7	7,1
	Total	226,2	92,4	51,0	22,7	239,3	24.0	19,3	15,6
July	L	57,1	18,5	10,8	5.4	54,4	5,4	5,7	4,7
	F	103,4	57,1	33,3	17,0	123,8	11.6	6,1	5,4
	Total	160,5	75,6	44,1	22,4	178.2	17.0	11,8	10,1
August	L	44,7	15,6	10,1	4,9	38,6	3,8	3,8	3,6
	F	101,6	60,6	36,2	18,8	132,2	11,8	4,9	4,9
	Total	146,3	76,2	46,3	23,7	170,8	15,6	8,7	8,5

Note: Comma represents decimal point.

in potassium, nitrogen, and phosphorus, and somewhat less in calcium and magnesium. The largest decrease in the amount of these elements in 1958 occurred in June-July and was relatively small in August.

If we calculate the content of each element in August (in percent) from that in June, we obtain the following ascending series in order of mobility:

mobility	Fe <	Al <	Si <	Ca <	Mg =	N <	P <	K
% of initial	100	90	83	72	65	65	53	46

The absolute values of the series change in other years, but the relative order of mobility remains the same.

The foregoing analytical material does not embrace the early spring period, when leaching of the forest litter and soil by snow meltwater and spring rains is greatest. Therefore it cannot characterize the absolute loss of separate elements by the forest litter.

Moreover, this material does not show where the elements lost by the forest litter go. We cannot tell on the basis of the foregoing analyses which part of the elements was leached from the litter by precipitation, which was removed by animals feeding on dead plant materials, and which was drawn into the new biological cycle. A certain part of the elements supplied to the forest litter during the biological cycle is later undoubtedly removed from the litter into the soil. This process has an exceptionally great effect on the formation of the profile of forest soils and their forest-growing properties.

Calculations of the elementary composition of parent rocks in volumetric percentages showed that 92%-94% of their volume is occupied by oxygen atoms, while all the remaining atoms account for 6%-8%. Thus, the elements needed by plants are very scattered among oxygen atoms in rocks. As a rule, there is no nitrogen in rocks. It follows from the foregoing that unchanged parent rocks represent a medium which is unfavorable for nutrition.

The upper part of the soil profile becomes enriched with humus, nitrogen, and ash elements during the biological cycle. This changes the soil medium inhabited by plants considerably. The concentration of biologically important elements in the root zone, which is achieved through the forest litter, creates more favorable conditions for the development of forest vegetation and improves the forest-growing properties of soil.

The upper part of the soil profile in the foregoing oak forests on poor quartz sand is noticeably enriched not only with humus and nitrogen, but also with aluminum, iron, manganese, calcium, magnesium, sulfur, and phosphorus. The accumulation of calcium and sodium is less pronounced. This enrichment of the upper part of the profile with the foregoing elements (Table 5) takes place at the expense of the underlying layer (D horizon, sample from a depth of 122-128 cm), which is richer in ash elements, during the biological cycle of elements. Elements brought by the temporary water table can also be drawn into the biological cycle in spring.

Not only the foregoing elements, but also a small amount of microelements is drawn into the biological cycle. An analysis of fallen oak leaves (Table 6) showed that a considerable amount of titanium, a considerably smaller amount of strontium, and even a smaller amount of the remaining elements (vanadium, chromium, nickel, copper, and lead) enters the soil with them. An especially small amount of cobalt and molybdenum is supplied to the soil by the fallen leaves, while the amount of zinc and tin is below the sensitivity of the spectral method.

A comparison of the content of microelements in the fallen leaves and in the forest litter gives a certain idea of the process of microelements accumulation in the forest litter. The accumulation

Table 5

Results of total chemical analysis of dark gray-brown, sandy loam forest soil underlain by silty clay loam. Sedge-goutweed oak stand (Ye. N. Plastinina, analyst)

Horizon	Depth, cm	Si	Al	Fe	Mn	Ca	Mg	K	Na	S	P	Oxygen difference
		In % of ignited soil										
A_1	0— 5	44,86	1,00	0,44	0,06	0,51	0.16	0,25	0,16	0,05	0,03	52,48
A_1	5— 10	44,79	0,67	0.52	0,04	0.47	0,16	0,28	0,16	0,09	0.03	52,79
A_1B_1	18— 23	45,25	0,49	0,35	0,04	0,19	0,22	0,20	0,16	0,04	0.01	53,05
B_2	54— 59	45,31	0,08	0,39	0,02	0.15	0,07	0,24	0,13	0,03	0,01	52,97
B_3	78— 83	45,50	0,40	0,26	0,01	0,20	0,07	0,18	0,08	0.06	0,01	53,23
D	122—128	39,27	4,53	2,29	0,03	0,52	0.36	0.90	0,23	0.06	0.04	51.77

Note: The first sample (A_1 0-5 cm) was taken immediately from under the litter.

Note: Comma represents decimal point.

Table 6

Content of microelements in fallen oak leaves and in the litter of an oak forest (M. A. Vinnik, analyst)[a]

Subject of analysis	Ash, %	Ti	V	Cr	Ni	Co	Mo	Cu	Zn	Sr	Pb	Sn
		In mg per 1 kg of substance dried at 100°C										
Fallen leaves	5.27	152,8	4,8	5,3	4,7	0,3	0,4	4,9	—	15,2	1,6	—
L layer	9,79	330.8	10,7	13,6	0,3	0,7	0,9	9,2	—	28,2	3,0	—
F layer	21.14	207,2	9,5	18,0	4,7	—	1,4	20,1	—	61,3	3,2	—

[a] The determinations were made on an ISP-22 spectrograph and were followed by measurements of the darkening of spectral lines on the microphotometer by the method of three standards. The sign — (minus) indicates that the content of the given element is below the sensitivity of the method. The litter samples were taken in August, 1957.

Note: Comma represents decimal point.

of titanium, strontium, vanadium, chromium, and copper is very distinct. Lead and molybdenum accumulate to a much lesser degree. The content of zinc and tin is below the sensitivity of the spectral method both in the fallen leaves and in the litter.

The content of all microelements investigated, except titanium, was minimal in the parent material (quartz sand) (Table 7). As was to be expected, the underlying material — silty clay loam, was richer in microelements. However, the content of molybdenum, zinc, strontium, tin, and lead in it was approximately the same as in the quartz sand. The difference being in the higher content of titanium, vanadium, chromium, manganese, nickel and to a lesser degree cobalt. Under these conditions the root systems of oak and its companions had to work hard to concentrate in the upper part of the soil profile the biologically important microelements which are very scattered in the soil-forming parent material and the underlying material.

In spite of such poor availability of microelements to vegetation, analyses (Table 7) show the accumulation of a number of microelements in the humus-accumulation horizon (A_1); accumulation is less pronounced in the lower-lying horizons (AB and B_1). The accumulation of titanium and manganese is most distinct, that of vanadium, chromium, nickel, and copper is much less pronounced, and there is very little cobalt and zinc. The behavior of strontium is peculiar. Even though it is contained in noticeable amounts in the fallen leaves and concentrates in the litter, its content in the upper soil horizons was not high.

The course of litter decomposition is very important for the supply of nutrients in the available form to forest vegetation. Soil and litter animals have an essential influence on the decomposition rate of fallen leaves. This is evidenced by the very large number of gnawed leaves composing the upper layer of the forest litter. It was noted that gnawed leaves are the first to be decomposed by microorganisms. Broadleaf forests are especially rich in soil and litter fauna. The discussion of this wide and complicated problem does not enter into the frame of the present communication.

Microbiological investigations made by Chastukhin in the foregoing oak forests (5) showed that recently fallen leaves are already covered with numerous black spots from the fruiting

Table 7

Microelement content in dark gray-brown sandy loam soil on quartz sand underlain by silty clay loam. (M. A. Vinnik, analyst).

Horizon	Depth, cm	Ti	V	Cr	Ni	Co	Mo	Cu	Zn	Sr	Sn	Pb	Mn
		In mg per 1 kg of soil ignited at 450°C											
A_1	1—10	5200	56	45	28	7	<5	37	500	<100	<5	<5	3300
AB	16—23	2800	30	48	9	5	<5	30	<100	<100	<5	<5	790
B_1	26—36	1900	28	52	8	<5	<5	31	<100	<100	<5	<5	100
B_2	45—55	500	10	39	6	<5	<5	26	<100	<100	<5	<5	100
B_3	80—90	810	22	34	8	<5	<5	25	<100	<100	<5	<5	100
D	120—130	4800	79	45	17	7	<5	35	<100	<100	<5	<5	270

bodies of ascomycetous fungi. Thus, the fungal action begins in a number of cases on leaves which are still attached to the tree. Chastukhin found the mycelium of basidium fungi and cellulose-decomposers (Trichoderma ligno, etc.) developing in the slightly decomposed (upper) layers of forest litter. In addition to basidium fungi he found strongly developing molds in the lower layer of the litter. Experiments on the decomposition of cellulose substantiated the fungal nature of this process in the oak forests studied.

To study the release and removal of nitrogen and ash elements from the forest litter, we used Büchner-type funnels, used for this purpose in the past by N. N. Stepanov and others. By placing leaves or litter with an undisturbed structure into this funnel we could analyze the composition of the percolate. A number of observations made during the work process lead us to the conclusion that the mineralization of the leaves or litter, taken individually, differs from that taking place when they are in contact with the soil.

To clarify this problem, Ye. M. Samoylova made an additional experiment in the autumn of 1958 on the decomposition of leaves under conditions more close to natural conditions. This experiment was made parallel to the study of the decomposition of litter in the funnels. Caprone bags were filled with oak and basswood leaves and placed on the soil surface in an oak-basswood stand. The walls of the bags were perforated to let the litter fauna through. The experiment was replicated 5 times, the agreement between the parallel experiments being good.

A comparison of the decomposition rate in the funnels and in the bags gave the following results, showing the decrease in weight in the course of a year in percent of initial weight:

Leaves:	Oak	Basswood
in funnels	16	37
in bags	27	60

Thus, the decomposition rate in the funnels was 1.6-1.8 times slower than in the bags. This shows that we cannot judge the loss of elements from the soil and draw any genetic conclusions from this on the basis of the difference in the removal of elements only from the litter and litter — soil, placed in lysimeters. The greatest decrease in weight took place during the spring-summer period, it was less in autumn, and very small (2%) in winter.

During the investigations we could observe regular differences in the nature and decomposition rate of the leaves of various trees. A relation was found between the rate of leaf mineralization and the content of nitrogen and ash elements in the leaves (4, 6). Decomposition by lower organisms, which possess a selective ability with respect to the nutrient substrate, is the more rapid the richer the leaves are in the foregoing elements. A role is also played by other properties of the leaves, such as hardness, the content of tannic substances, etc.

Basswood, ash, hazelnut, and elm leaves decompose most rapidly, since they constitute a favorable substrate for soil and litter animals and microorganisms. Oak and aspen leaves were found to be most resistant to decomposition. Oak and aspen leaves decompose more rapidly when mixed with hazelnut, ash, and basswood leaves.

According to anatomical investigations (4), the mesophyll is decomposed first and then the epidermis and a large portion of small cells. The leaf veins are preserved longest. Chemical analyses showed a considerable decrease in the content of protein, bitumen, and hemicellulose and a slightly lesser decomposition of cellulose during the winter and early spring periods. At the same time there was a considerable accumulation of water-soluble organic substances. During the following summer-autumn period cellulose decreased further and the content of water-soluble organic compounds decreased sharply. At the same time re-synthesis of hemicellulose took place and the amount of nonhydrolyzable residue increased as a result of the formation of humic substances.

The analytical material on the removal of ash elements from decomposing leaves obtained for a number of years (1950-1960) is so erroneous that we cannot present it here. This limits us to the presentation of our final general conclusions.

Potassium is released most rapidly during the decomposition of leaves. Under the conditions of lysimetric experiments, basswood leaves lost more than 90% of the initial amount of potassium each year; elm and hazelnut leaves lost 85%; ash, maple, and oak leaves lost 80%. The foregoing amounts of potassium were removed from the leaves of many trees as early as during the early spring period. The removal of sulfur, phosphorus, and magnesium was considerably slower, and that of calcium was even slower than that. Oak, ash, basswood, and hazelnut leaves lost 40%-50% of their initial calcium content in the course of a year. As in other investigations, there was a relative accumulation in the products of leaf decomposition of silicon, aluminum, and iron, which are removed most slowly from the leaves.

The amount of elements removed beyond the soil profile was assessed in a special experimental plot of 35 m² for the study of horizontal flow. The description of this plot is given in an earlier publication (2), which included data for the first 4 years of observation (1954-1957). Now we can present data for 7 years (1954-1960).

In all these years horizontal moisture flow took place only during the snow melting period during the second half of March and April, sometimes extending to the first half of May. In 1957 slight percolation was observed in the second half of February because of a prolonged warm spell in winter. There was some percolation amounting to a total of 2.5 metric tons/ha in the rainy summer of 1958. The total annual percolation during 7 years varied from 15 metric tons/ha (1960) to 60 metric tons/ha (1958). Fluctuation in the flow depends on the spring storage of moisture in soil, moisture content of snow cover at the beginning of snow thaw, manner of thawing and effect of

Table 8

Relationship between the supply of elements from the litter and their removal by percolation in a sedge-goutweed oak stand

Supply and removal of elements	Si	Al	Ca	Mg	K	P	S	N
1953-1954								
Supplied by litter, kg/ha	35,4	5,5	97,5	—	42,5	8,7	—	50,9
Removed by percolation, kg/ha	0,034	0,147	3,277	—	0,208	Trace	—	—
Same, % of supply	0,10	2,67	3,36	—	0,49	0	—	—
1954-1955								
Supplied by litter, kg/ha	34,8	5,7	100,9	—	42,8	8,7	—	50,3
Removed by percolation, kg/ha	0,013	0,295	2,761	—	0,093	Trace	—	—
Same, % of supply	0,04	5,17	2,74	—	0,22	0	—	—
1955-1956								
Supplied by litter, kg/ha	29,0	5,5	83,9	—	35,6	7,4	—	42,4
Removed by percolation, kg/ha	0,019	0,528	4,013	—	0,709	Trace	—	0,752
Same, % of supply	0,07	9,60	4,78	—	1,96	0	—	1,78
1956-1957								
Supplied by litter, kg/ha	24,8	3,3	72,6	—	26,5	6,6	—	42,1
Removed by percolation, kg/ha	0,09	1,334	1,384	—	0,253	0,003	—	0,415
Same, % of supply	0,37	39,39	1,19	—	0,95	0,05	—	0,99
1957-1958								
Supplied by litter, kg/ha	24,6	3,2	54,4	8,5	23,8	4,4	4,1	35,2
Removed by percolation, kg/ha	0,05	0,12	2,21	0,21	0,09	0,009	0,05	0,71
Same, % of supply	0,21	3,8	4,1	2,5	0,4	0,2	1,2	2,0
1958-1959								
Supplied by litter, kg/ha	22,6	2,9	49,8	7,7	21,7	4,6	3,8	31,9
Removed by percolation, kg/ha	0,27	0,17	0,99	0,10	0,02	0,001	0,006	0,18
Same, % of supply	1,2	5,9	2,0	1,3	0,009	0,02	0,16	0,6
1959-1960								
Supplied by litter, kg/ha	29,3	3,5	80,4	11,3	30,0	10,5	5,6	36,2
Removed by percolation, kg/ha	0,11	0,006	0,33	0,03	0,02	0,002	0,007	0,08
Same, % of supply	0,37	0,17	0,41	0,27	0,07	0,02	0,13	0,22

Note: Comma represents decimal point.

spring rains.

The active reaction of all the percolation waters during these years was close to neutral, varying from 6.9-8.0. Of all the elements, calcium was removed in the greatest amounts during all these years, while much less potassium was removed (Table 8). For magnesium we have data only for the last 3 years which show that magnesium is removed in much lesser amounts than calcium. Only very insignificant, sometimes unassessable amounts of phosphorus were removed; the removal of sulfur was also small, but greater than phosphorus. The considerable removal of aluminum when percolation waters contained a small amount of silicon, was unexpected. The removal of silicon increased considerably in the last two years (1959, 1960), exceeding that of aluminum in 1960. No definite relationship was found between the volume of percolating water and the removal of the foregoing elements with it.

The quartz sands on which the soils studied developed do not contain soluble salts and the source of the water-soluble salts removed by percolation is the organic substance produced by higher plants and the dead organic substance decomposed by lower plants and soil and litter animals. If we express the amount of elements removed by percolation in percentages of the amount supplied by the fallen leaves, we will obtain indices which characterize the mobility of a corresponding element under given conditions (Table 8).

We constructed the following mobility series on the basis of such indices for 5 elements for which we had 7-year data:

1954 Ca > Al > K > Si > P
1955 Al > Ca > K > Si > P
1956 Al > Ca > K > Si > P
1957 Al > Ca > K > Si > P
1958 Ca > Al > K > Si > P
1959 Al > Ca > Si > P > K
1960 Ca > Si > Al > K > P

The sequence of the foregoing series is rather consistent. Only in 1954 and 1958 did Al and Ca change places, whereby the difference in the mobility of Al and Ca in 1958 was within the accuracy of the investigations. K changed places with Si and P in 1959. We did not find any explanation for the low mobility of potassium in 1959. In 1960 when percolation was at its lowest, the removal of silicon increased and that of aluminum decreased.

More detailed mobility series can be constructed on the basis of investigations in the last 3 years:

1958 Ca > Al > Mg > N > S > K > Si > P
1959 Al > Ca > Mg > Si > N > S > P > K

According to B. B. Bolynov the migration series is: S > Ca > Mg > K > P > Si > Al.

These mobility series differ essentially from the migration series in the weathering crust, compiled by Polynov (1). Aluminum, which is very mobile in the soil under an oak forest, is the least mobile in the Polynov series for the weathering crust. Potassium is more mobile in the weathering crust than in the soil studied. Phosphorus, which is the least mobile under soil conditions, occupies a central position of mobility in the series for the weathering crust. Sulfur, which is the most mobile in the migration series of Polynov, is not very mobile in the soil and is close to phosphorus with which it has a lot in common, from the biological point of view.

The difference between mobility series compiled on the basis of data on the release of elements during the mineralization of the oak forest litter and on their average removal by percolation is interesting:

Release from the litter: K > P > N = Mg > Ca > Si > Al
Removed by percolation: Al > Ca > Mg > N > K > Si > P

Potassium is removed from the plant residue most rapidly, but according to its removal beyond the soil profile it belongs to the least mobile elements. Aluminum, on the contrary, is very slowly released during the decomposition of the litter, but being released it acquires a relatively high mobility. The behavior of phosphorus and calcium shows similar differences.

The foregoing is caused by the fact that the solutions infiltrating into the soil from the forest litters change their composition in doing so, since the root systems of higher plants and microorganisms take up the elements selectively. A certain portion of the elements is retained because of the adsorption capacity of the soil. At the same time an increase in the content of elements is possible as a result of dissolution and exchange. This is somewhat similar to partition chromatography but complicated by biological processes. The soil is not an inert medium, and the solutions filtering through it undergo many changes in their composition and properties.

Since various formations draw into the biological cycle unequal amounts of elements and at different ratios, while soils differ from each other in their interaction with the infiltrating solutions, there is no basis to assume that there is only one series of mobile elements for all soils.

The influence of the nature of forest vegetation on the content of elements removed by percolation may be judged from the results of the analysis of the waters of forest streams. For this purpose we used streams with a small catchment basin, lying within the limits of an oak, aspen, or pine forest only. Beginning with 1955 we started with the chemical analysis of the water of such streams during the snow melting period. Now we have data for 6 years. We took the water of the Usmanka River for comparison (Table 9).

The analyses showed considerable fluctuations in the chemical composition of dissolved compounds in the streams from year to year. There was a certain parallelism between the fluctuations in the content of certain elements in the percolated water of the plots (Table 8) and that of the streams (Table 9). Thus, the highest amount of aluminum found in the

Table 9

Abbreviated results of the chemical analysis of water of temporary streams and the Usmanka River (Analyzed by M. K. Sviridova and M. Ye. Popova)

Names of streams and rivers	Nature of watershed	Date	pH	Si	Al	Ca	K	P	S	N
				In mg/liter						
	1955									
Krutovskiy	Oak-covered	March 31	—	0,65	—	62,50	—	0,24	—	—
Pridorozhnyy	Same	Same	—	0,70	—	74,50	—	0,50	—	—
Cherepakhinskiy	Aspen-covered	"	—	0,70	—	44,35	—	0,24	—	—
Usmanka River	Covered by a mixed-forest	March 30	—	0,84	—	30,24	—	0,22	—	—
	1956									
Krutovskiy	Oak-covered	May 30	7,6	0,45	13,94	99,19	11,71	Trace	—	15,16
Pridorozhnyy	Same	Same	7,8	0,39	11,69	99,19	17,21	"	—	8,10
Cherepakhinskiy	Aspen-covered	"	7,5	0,37	13,97	63,71	12,91	"	—	6,95
Usmanskiy	Pine-covered	"	7,4	0,22	10,89	32,26	15,54	"	—	12,74
Usmanka River	Covered by a mixed forest	"	7.5	0.16	14,72	73,38	18,62	"	—	10,79
	1957									
Krutovskiy	Oak -covered	April 9	7,0	1,70	21,72	24,12	5,08	0,06	—	3,36
Pridorozhnyy	Same	"	7,2	1,71	20,54	22,68	1,89	0,06	—	4,48
Cherepakhinskiy	Aspen-covered	"	7,2	1,80	16.53	11,88	0,70	0,05	—	5,60
Usmanskiy	Pine-covered	April 11	6,7	1,61	12,30	6,48	1,01	0,07	—	4,48
Usmanka River	Covered by a mixed-forest	April 12	6,6	1,69	12,30	11,52	0,50	0,06	—	6,72
	1958									
Krutovskiy	Oak-covered	April 15	8,0	0,87	2,36	31,57	1,24	0,11	1,60	15,9
Pridorozhnyy	Same	"	8,0	0,81	2,37	18,42	1,49	0,03	0,72	14,9
Cherepakhinskiy	Aspen-covered	"	7,8	0,62	2,30	17,10	2,14	0,09	1,60	14,8
Usmanskiy	Pine-covered	"	6,0	0,58	2,42	8,04	1,14	0,09	2,40	15,1
Usmanka River	Covered by a mixed-forest	"	7,6	0,47	2,36	8,04	0,40	0,09	4,01	14,4
	1959									
Krutovskiy	Oak-covered	April 4	7,0	11,40	0,18	26,46	0,36	0,01	0,33	1,34
Pridorozhnyy	Same	"	7,0	11,44	0,20	43,20	0,06	0,02	0,16	1,12
Cherepakhinskiy	Aspen-covered	"	7,0	8,19	0,18	10,80	0,17	0,01	0,01	1,57
Usmanskiy	Pine-covered	April 5	6,6	7,89	0,19	12,26	0,09	0,01	0,30	1,60
Usmanka River	Covered by a mixed-forest	"	6,8	7,32	0,18	21,60	0,17	Trace	0,23	0,78
	1960									
Krutovskiy	Oak-covered	April 15	7,4	8,15	0,31	17,91	0,47	0,15	0,60	4,45
Pridorozhnyy	Same	"	7,4	8,59	0,40	26,87	0,59	0,14	0,11	2,37
Cherepakhinskiy	Aspen-covered	"	7,5	7,39	0,46	13,74	0,59	0,18	0,11	13,24
Usmanskiy	Pine-covered	April 16	7,0	6,57	0,38	6,18	0,82	0,16	0,48	8,80
Usmanka River	Covered by a mixed-forest	April 15	7,5	5,48	0,43	13,90	0,41	0,17	0,27	2,37

Note: Comma represents decimal point.

percolation water from the plots in 1957 coincides with its highest amount in the water of the streams. The same is true of the highest content of calcium and potassium in 1956. In 1959 and 1960 the amount of silicon in the percolation water from plots and in the streams increased.

Stream water, fed from watersheds covered with various forests, differed essentially in calcium content. The water of streams with pine-covered watersheds was poor in calcium and had a more acid reaction than the water of streams fed from watersheds occupied by oak forests. The water streams from watersheds covered with aspen occupies an intermediate position. The reason for this difference is that more calcium is drawn into the biological cycle by an oak forest than by a pine forest. The reasons for the lesser removal of calcium from watersheds occupied by aspen is not clear, since the litter of an aspen forest has a somewhat higher calcium content.

The water of the Usmanka River is poorer in calcium than the water of streams in the oak forest, but richer than the water of streams in the pine forest. We must consider that the upper reaches of the Usmanka River lie partly in the steppe belt. Even though snow melting begins earlier in forest-free watersheds, they still have a certain effect on the composition of the water in the Usmanka River during the snow melting period in the forest.

We can see from the foregoing material that the nature of the forest litter formed in various forests affects not only the properties of soils developing in a forest, but also the composition of soil water feeding forest streams and rivers, and by the same token the composition of larger rivers. This relates the biological cycle of elements under various vegetation to the wider problem of the large geological cycle of substances in nature.

Conclusions

1. The annual amount of foliage and litter in an oak forest undergoes considerable fluctuations depending on the weather conditions in individual years. Together with this the amount of nitrogen and ash elements entering the soil by way of leaf-fall changes.

2. The leaching of individual elements released during the decomposition of the litter in an oak forest takes place in the following order: Fe < Al < Si < Ca < Mg = N < P < K.

3. Part of the foregoing elements is selectively absorbed by living organisms and the solid phase of the soil during their percolation through the soil. The order in which the elements are removed by percolation differs from their order of removal from the forest litter. Potassium and phosphorus are especially clearly retained in the soil.

4. The water of streams having watersheds occupied by various types of forests differs considerably by content in dissolved salts. The water of streams fed from watersheds occupied by oak and aspen forests are richer in calcium salts than the water of streams with pine-covered watersheds.

5. The characteristics of the biological cycle of elements under various types of vegetation affect the composition of dissolved compounds in river waters, and, consequently, the large geological cycle of substances in nature.

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MOVEMENT OF COLLOIDAL AND CLAY PARTICLES IN SOILS

(Problem of Leaching and Podzolization)

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We determine the movement of highly disperse particles in soils developed on homogeneous parent material from the formation of horizons rich and poor in clay, from white powdering and concretions, from the presence of optically-oriented clay in the pores (30, 31, 46, 52, 60), and from the presence of colloids in lysimetric solutions.

Movement takes place in one case in the form of true solutions, in other cases in the form of colloids and suspensions. The chemical composition of the moving substance may be mineral, organic, or organo-mineral.

The problem of whether the movement of highly disperse particles in gay forest soils, brown forest soils, and sod-podzolic soils takes place with or without the particles being decomposed has recently been discussed in special journals and at meetings of soil scientists (10, 23, 32, 45, 46, 53, 55, 57-68). The first category of processes is called lessivage (59, 60) (illimerization, clay removal) (53), the second, podzolization. As pointed out by Duchaufour, these processes are genetically related to each other, whereby the movement of clay without being decomposed is the primary stage of subsequent decomposition. Certain authors suggest that soil be classified according to the degree in which these processes are expressed. This suggestion has not been generally accepted and for good reasons: the objective evidence for distinguishing these two processes is debatable, and in a number of cases, insufficient. Later we will critically examine this evidence.

History of the Problem

As we know, minerals do not only form and modify in the soil, but they are also being decomposed and moved. The movement of fine soil particles had been studied a long time ago, whereby Russian soil scientists contributed considerably to its clarification and substantiation with experimental data.

V. V. Dokuchayev (9) separated podzolic soils into an individual group according to morphological indices, which gave reasons to believe that the fine particles in these soils move from the upper into deeper horizons. A contemporary of Dokuchayev, Geogiyevskiy (9), believed that this movement is accompanied by the decomposition of clay particles. The latter opinion was then developed by many Russian scientists.

N. M. Sibirtsev (42) pointed out that an acid decomposition of soil occurs on podzolization as a result of biochemical processes and that the products of this decomposition are being removed downward along the profile. Glinka (11, 12) did not attach any importance to the decomposition of soil particles at first, but in his last work (12) he wrote on the basis of his own observations and the experiments of Gedroyts (7) that: "the processes of leaching and illuviation of colloids and suspensions play an essential role in podzol formation, while acid decomposition is only an accompanying process" and further: "In our opinion, the powdering (we mean the powder at the surface of aggregates and its related whitish podzolic horizon — NH) is very fine quartz sand which remains at the surface of clay blocks after the finer clay particles and iron hydroxides have been removed from this surface" (12, p. 366).

I. V. Tyurin (48) notes the breadth of K. D. Glinka's views in which he recognizes the movement of colloids with and without decomposition.

K. K. Gedroyts showed soil formation from the physicochemical point of view, stressing the phasic nature of this process. In his opinion, the hydrogen ion of the solution displaces exchangeable cations, which leads to the dispersion and decomposition of the adsorption complex, while the decomposition products move downward.

K. K. Gedroyts wrote about the decomposition of the adsorption complex by water: "In order to avoid confusion I must explain what I mean here under the "decomposition" of the adsorption complex of the soil. If the magnitude of the adsorption complex of the soil decreases for any reason, I say that the adsorption complex of the soil is being decomposed. But this decomposition can take place in two ways: the adsorption complex may be removed from the soil as such, and its amount in the soil will naturally decrease; on the other hand, water may cause decomposition, by breaking up the complex compounds into simpler compounds and then removing them uniformly or in various ratios, or by removing one and not removing the other products of the decomposition of the adsorption complex" (7, p. 358). Consequently, Glinka and Gedroyts recognized the movement of fine soil particles with and without decomposition. In a work, devoted to the formation of solonetzes and solods, Gedroyts again explains in detail his point of view about the decomposition of the adsorption complex, as we can see from the following: "The leaching of humus and the decomposition of aluminosilicates of the core of the adsorption complex in solonetzes and solonetzic soils under the influence of leaching the soil by atmospheric waters finally leads to a new soil formation, which in certain cases is morphologically similar to podzolic soils with one or the other degree of podzolization" (7, pp. 471).

In the opinion of Vil'yams (6), soil is being decomposed during podzol formation under the influence of crenic acids, which form from forest litter as it is being decomposed by fungi. Extensive experimental data were obtained by soil scientists in the simulation of the movement of colloids, as well as in the study of the chemical nature of concretions forming in sod-podzolic and other soils (1, 25, 26, 30, and others).

In 1921, M. M. Filatov (50, 51) made experiments on the movement of iron and aluminum hydroxides to explain the rate of movement of ortsand in sand deposits and also to determine the role of mineral and organic substances in the process. The laboratory experiments of the author were accompanied by field observations.

A similar series of experiments was made at the same time by Tyuremnov (46). Basing himself on the opinion of Sibirtsev that soil formation is the result of the influence of humic acids on parent material, he studied the influence of acid solutions on the change in soil texture in order to explain the causes for the formation of the eluvial horizon in podzolic soils. As a result of his investigations, Tyuremnov came to the conclusion that there are two processes: the movement of particles and their decomposition.

Gemmerling (8) studied ortstein (concretions) in podzolic soils in detail. He established a difference between the chemical composition of concretions depending on their size and formation conditions. In addition to concretions, Gemmerling studied the texture and chemical composition of coatings of structural units of the soil. The coatings differ chemically from ortsteins in that they have a higher content of iron, manganese, and humus, i. e., a number of elements accumulates in these formations.

Ye. V. Arinushkina (4) conducted extensive research on ortsands, determined their chemical composition and the composition of substances removed in the Tamm and Schlesing extract. One of the important conclusions derived from the work of Arinushkina is that ortsands contain free sesquioxides and silica, which have apparently accumulated as a result of the decomposition of soil minerals. At the same time, the small amount of silicate forms of silica, sesquioxides, calcium, magnesium, and other elements in these new formations indicate the presence of a large amount of undecomposed minerals. Thus, we can assume that there are two simultaneous processes: the movements of soil particles with and without decomposition. It is also important to note that iron, aluminum, and silica accumulate in the ortsands of podzolic soils, while there is no accumulation of manganese, phosphorus, and sulfur. As we know, manganese, and sometimes phosphorus and calcium accumulate in other soils (26).

The interest in the study of ortsteins and similar new formations has not weakened to our day (17, 20, 24, 25, 30, 31, 33, 41), since new formations serve as evidence and indicators of the decomposition and movement of particles, of the intensity of soil formation, and its direction.

Formation of Concretions and their Composition

Ground or surface waters play a considerable role in the formation of concretions. Iron, manganese, aluminum, organic compounds, as well as clay minerals may be contained in them in a dissolved or colloidal form. Under favorable oxidation-reduction conditions soluble ferrous iron compounds are being oxidized by the oxygen of the air, change to oxide compounds, i. e., less readily soluble forms, and therefore precipitate and sometimes form concretions. Concretions may form either during the periodic movement of water downward along the profile or during the lateral movement of water, or, as assumed by Nogina (29), during the upward movement of solutions. The difference in the conditions of formation of concretions determines the difference in their composition. As a rule, all concretions contain a considerable amount of silicic acid, aluminum usually occupies the second place, then iron, manganese, and the other elements (Table 1). Concretions are often rich in organic substances. The presence of a large amount of silicate acid (50%-80%) indicates that concretions contain primary minerals (including quartz) and secondary minerals. The ratio between the amount of iron and aluminum varies, but the former rarely predominates over the latter. If we consider that the atomic weight of aluminum is smaller than that of iron, then there is almost always more aluminum than iron, when reduced to equivalents. This is attributable first of all to the fact that aluminum exists in the ionic form at a pH of <5.0 and iron oxide at a pH of <3.5, and secondly to the fact that there is more aluminum in many minerals and soil than iron.

The concretions consist of a mixture of clay and non-clay minerals, and also of amorphous and hydrophilic substances, in particular sequioxides and humus. The thermograms given below (the large area is that of the first endothermic effect) substantiate this opinion rather conclusively (Fig. 1).

Decomposition Rate of Minerals

The chemical and mineralogical composition

Table 1

Total chemical composition of new formations (crusts, ortstein, iron-manganese concretions, nodules, ortstand), % of absolutely dry sample

Soil	Region investigated	Humus	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	MnO	$\frac{SiO_2}{R_2O_3}$	Author
Podzol	Moscow Oblast'	Not det'd.	65,2	10,0	11,1	Not det'd.		5,13	6,8	Gemmerling (8)
Strongly podzolic	Same	"	72,8	10,7	9,88	"		2,27	7,5	Same
Sod-podzolic	"	"	68,4	10,4	12,0	"		6,5	6,4	Popazov (30, 31)
Strongly podzolic	"	3,0	65,4	12,6	11,2	2,46	1,36	5,24	5,7	Gradusov (17)
Same	"	2,6	69,9	7,83	9,08	2,06	2,25	3,06	7,6	Same
Same, ortsand, B_2	"	0,23	87,9	4,21	3,1	0,63	0,44	0,12	25,0	Arinushkina (4)
Same, B_3	"	0,37	87,2	4,1	3,2	0,50	0,47	0,05	23,3	Same
Moderately podzolic, ortsand, B_2	"	0,25	85,1	7,57	2,5	0,51	0,48	0,05	15,5	"
Podzolic-gleyey B_2	"	0,20	74,9	13,21	4,16	1,0	0,47	0,16	7,5	"
Same, B_3	"	0,25	70,1	15,1	5,53	1,0	1,1	0,42	6,1	"
Meadow, A_{plowed}, Profile 202	"	4,56	46,5	12,2	26,5	2,5	2,1	4,37	2,7	Gradusov (17)
Gray forest	Ryazan' Oblast'	2,83	78,6	10,3	8,0	0,74	0,60	2,39	4,6	Same
Same	Same	0,47	68,3	14,3	15,5	0,6	0,3	0,2	5,6	"
Gray-br. forest soil of flood-plain oak stands	Vladimir Oblast'	3,18	64,4	13,6	16,8	1,2	0,5	0,4	5,2	"
Same	Same	3,15	68,4	12,9	14,2	1,3	0,4	0,4	5,1	"
Brown forest, A_1	"	0,35	81,6	9,3	8,2	0,7	0,6	0,3	9,3	"
Meadow	"	6,31	42,0	12,2	30,0	1,73	0,93	10,8	2,3	"
Same	"	3,74	56,3	7,94	19,4	2,20	0,61	6,18	4,5	"
", concretions 2-2.5 ml	Amur Oblast'	1,09	37,3	20,9	10,8	5,43	1,55	13,3	2,3	Kovda and oth. (25)
Same, 1-1.5 ml	Same	5,76	38,8	14,9	17,9	5,8	1,29	9,1	2,4	Same
Same	"	Not det'd.	52,3	13,0	23,7	4,87	2,04	0,75	3,2	Roslikova (41)
Same, size of the conretions > 5 ml	"	"	56,5	7,22	24,1	0,84	1,78	8,08	3,9	Same
Same, 5-3 ml	"	"	57,9	11,1	18,1	0,92	Not det'd	6,20	4,5	"
Same, 3-2 ml	"	"	54,5	5,3	26,1	0,91	1,46		4,7	"
Same, 2-1.5 ml	"	"	53,8	10,1	29,2	0,84	1,34	0,61	2,8	"
Same, 1-0.5 ml	"	"	49,0	8,4	38,9	0,63	0,88	0,34	2,5	"
Yellow earth-podzolic	Azerbaydzhan SSR	"	47,2	20,4	16,4	1,84	6,8	11,3	2,59	Gorbunov
Same, frac. <0.001 mm in diam.	Same	"	43,9	24,4	18,7	1,99	8,6	1,53	2,02	Same
Podzolic on a red crust	Georgian SSR	"	64,0	17,1	14,7	0,4	0,2	2,1		Polynov (34)
Solod	Kazakhstan	"	56,1	15,0	14,4	Not det'd.		10,1	3,9	Popazov (31, 30)
Same, Profile 20	Askaniya-Nova	8,36	51,8	13,3	17,5	1,05	0,48	6,92	3,5	Gradusov (17)
"	Skavodskaya exp. sta.	5,14	63,2	15,8	11,1	0,80	0,51	4,17	4,7	Same
"	Same	6,03	61,8	17,5	10,3	0,56	0,50	5,87	4,4	"

Note: Comma represents decimal point.

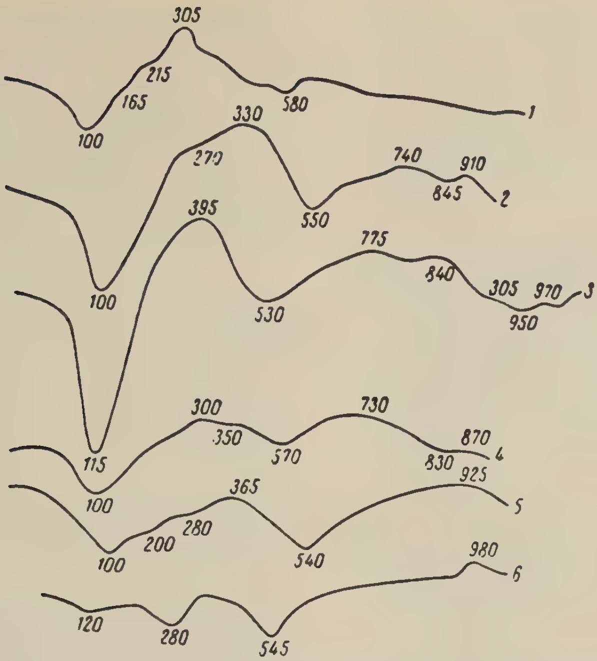

Fig. 1. - Thermograms of concretions and new formations. 1 - iron hydroxide gel, Yakhroma River flood plain; 2 - concretions from meadow soil, Klyaz'ma River, Profile 202, A_{plowed} 26-37 cm, diameter of concretions 3-5 mm; 3 - same, Klyaz'ma River, Profile 202, A_{plowed} 26-37 cm, diameter of concretions <5 mm; 4 - concretions from gray-brown forest soil in a flood-plain oak stand, Profile 12, Vladimir Oblast'; 6 - laterite, Profile 273, 50-60 cm, Vietnam.

of concretions shows that they contain the decomposition products of soil minerals. The causes for the decomposition of minerals are varied. The rate of these processes depends on the quantity and forms of organisms, the reaction of the medium, oxidation-reduction conditions, temperature, the water and aeration regime of soils, etc., but an especially important role is played by the crystallochemical nature of the minerals, the degree of their dispersion and crystallization, and the combination of minerals.

Ye. I. Parfenova and Ye. A. Yarilova believe that large soil particles, i.e., primary minerals, are subject to more intense weathering than fine particles, i.e., secondary minerals (32), whereby they refer to their laboratory experiments to substantiate their opinion.

The stability and decomposition of minerals must be examined in close relation to 3 groups of causes: 1) internal, i.e., determined by the structure, composition, and properties of the minerals themselves; 2) external, determined by bioclimatic conditions under which the minerals exist; and 3) the state of the minerals, i.e., their dispersion, combination with other minerals, etc. It is not enough to divide minerals according to their stability depending on whether they belong to coarsely or finely-dispersed minerals or whether they are primary or secondary minerals.

Let us give you a number of examples to illustrate the foregoing. As we know, the solubility of calcite depends on the concentration of carbon dioxide in water, while carbon dioxide has little effect on the solubility of other minerals. The solubility of minerals in acids depends greatly on their properties and dispersion. According to our data muscovite, kaolinite, halloysite, and montmorillonite, ground to a roentgenographically amorphous state and then treated with 0.2 N hydrochloric acid, showed a differing solubility. We found 66% of the total content of aluminum oxide in halloysite, 37% of its content in kaolinite, and more than 90% of its content in montmorillonite in hydrochloric acid extracts. These experiments indicate the tremendous importance of the dispersion of minerals and their nature.

The stability of minerals in relation to their properties also varies under the influence of water. Thus, potassium can be removed from muscovite with water, as a result of which it changes to hydromica. The effect of water or quartz or goethite ($Fe_2O_3 \cdot H_2O$) is insignificant at a neutral reaction. Kaolinite, gibbsite, and many other minerals behave similarly. Our experiments showed that the solubility of minerals depends also on the nature of acids. For instance, kaolinite decomposes less readily in hydrochloric acid than it does in sulfuric acid, while the opposite is true for montmorillonite.

It is well known that under similar conditions calcium feldspar weathers more rapidly than potassium feldspar. Under similar conditions granite is more stable than basalt. Hydromicas are rather rapidly decomposed in podzolic soils, while the same hydromicas are preserved in sierozems (under dry conditions) and are found in predominant amounts in their clay fraction.

The decomposition of primary minerals is most pronounced in laterites, besides quartz. If these soils develop on basic rocks there are little primary minerals left in them, while kaolinite, goethite, and gibbsite are left among secondary minerals. Laterites, developed on acid rocks (granites), always contain quartz (in considerable amounts), and sometimes potassium feldspars. Feldspars and micas are always present in the majority of other soils, which points to their stability under these conditions.

Thus, all the facts indicate that the decomposition of primary and secondary minerals depends on many factors, and therefore one and the same primary or secondary mineral can be resistant or not resistant to decomposition. Biological processes play an important role in the decomposition of primary minerals and the formation of secondary minerals. This was especially considered by V. I. Vernadskiy and B. B. Polynov. However, they were not able to study the composition of newly-formed minerals in detail and the results of X-ray investigations conducted at the request of Polynov were put under doubt by him (35, p. 405). New data on the formation of secondary minerals from primary minerals, depending on time and the weathering conditions of the latter, have been obtained recently from X-ray thermal, and electron-microscope investigations (14, 16, 44). These and other data indicate the following scheme of mineral transformations: primary minerals (feldspars, micas, etc.) → hydromicas → montmorillonite, beidellite → kaolinite → halloysite → goethite, gibbsite. It is only natural that there could be considerable deviations from this scheme under particular soil conditions.

Evidence of the Movement of Colloids and Clay with and without Decomposition

In order that colloids and clay be able to move in the soil they must be in the form of a sol or highly swollen gel. Polarizing clay represents one of these states. Soil drying and freezing increases the concentration of coagulant ions in the solution, lower the charge and hydration of colloids and thus lower the mobility of clay. The most hydrophilic, highly dispersed minerals, such as montmorillonite, allophane, certain hydromicas, organic substances, freshly precipitated silica, etc. move more rapidly than hydrophobic minerals under the same conditions. The latter usually move under the protection of hydrophilic minerals. For instance, sesquioxides, the minerals of the kaolinite group, quartz particles, etc., acquire mobility under the protection of organic substances and such hydrophilic minerals as montmorillonite and allophanes (2, 3, 56).

One may find that substances moving in soils change from the colloidal state into a true solution or vice versa. For instance, bivalent iron may exist in solution when the pH is wide and move together with surface and ground waters. If the solutions find themselves under oxidizing conditions, bivalent iron changes into trivalent iron and precipitates in the form of a hydroxide gel. When oxidizing conditions are replaced by reducing conditions, the colloids may change again into a true solution.

Foreign soil scientists (59, 60, 62, 63, etc.) have suggested the following indices for distinguishing the movement of highly disperse particles with and without decomposition:

1. The movement of colloids and clay without decomposition is detected by the presence of optically-oriented clay, which is allegedly absent in soils where decomposition takes place.

2. If there is no decomposition, the chemical composition of the clay fraction should be constant in various layers of the profile, and vary if decomposition takes place.

3. If there is not decomposition, the mineral composition of highly dispersed soil particles should be similar in all horizons of the profile, and differ if decomposition takes place.

Let us examine each of these indices. Polarizing clay consists of oriented clay mineral crystals. The orientation of clay minerals is a property governed by their layered structure and lamellar form. A water medium promotes the oriented arrangement of clay mineral crystals, which serves, as we know, as the basis for the preparation of samples for X-ray analysis. X-ray patterns of oriented samples give brighter reflections from basal planes, which is important for the interpretation of X-ray photographs. Oriented samples may be obtained artificially by allowing the suspension to settle; a similar phenomenon, i. e., the orientation of clay, takes place in soil pores when they fill with water.

The presence of isotropic particles in polarizing clay, such as the decomposition products of colloids, cannot always be detected under the microscope, since they are masked by oriented clay. From this it follows that the presence of polarizing clay does not always prove the absence of the decomposition products of minerals. Certain authors believe that polarizing clay is a monomineral formation, for which there is not sufficient proof, in our opinion, since we have no reason to ascribe to this formation the name of a new, formerly unknown clay mineral — polynite (32) and try to calculate its chemical formula. Oriented clay is most probably a polymineral formation, consisting of highly disperse minerals and an admixture of amorphous substances, including humus.

The mineralogical composition of polarizing clay must be the same as that of the general highly disperse portion of the soil. According to our data, sod-podzolic, gray and brown forest soils and solonetzes, developed on fine earth parent material or when they are not subject to intense leaching, usually contain minerals of the montmorillonite group, mixed or in other combinations with hydromicas and sometimes with amorphous colloids. If, however, such soils develop on igneous rock or are subject to intense leaching they usually contain a considerable amount of minerals of the kaolinite group. Since kaolinite is a hydrophobic mineral, in order to flow and be oriented, the clay containing kaolinite must have protective hydrophilic colloids, whereas no protective colloids are necessary for montmorillonite and analogous minerals, since they are hydrophilic and highly disperse themselves. In principle, the movement and orientation of clay minerals takes place in almost every soil (27). This is also substantiated by laboratory experiments during the washing of soil with water (57). Drying, freezing, and the presence of coagulant ions in the soil interfere with the formation of oriented clay.

Let us examine another index — the chemical composition of the clay and colloidal fractions. Certain investigators believe that leaching and podzol formation can be distinguished by a comparison of the chemical composition of the highly disperse fraction of the upper and lower soil horizons. This opinion is based on the fact that minerals in the A_2 horizon break up during podzol formation, while new secondary minerals of a different chemical composition form in the lower part of the profile from the products of this decomposition. Only a mechanical movement of disperse particles without decomposition occurs during lessivage.

In fact, a number of works (5, 10, 28, 53) show a difference in the chemical composition of clay and colloids in individual soil horizons, especially as far as iron, aluminum, and silica are concerned. It would seem at a first glance that this is a very reliable sign, but in practice we will often find such cases when the clay fraction is similar in its chemical composition at various depths in sod-podzolic soil. Such a contradiction can be explained in the following way. First of all, the decomposed portion of clay and colloids is often a small fraction of the non-decomposed portion and therefore a change in chemical composition cannot always be detected. This opinion is substantiated not only by similar chemical composition, but also by thermograms and X-ray patterns of colloids or clay removed from samples taken from various depths of the profile. When a considerable decomposition of minerals takes place, the lines of X-ray patterns become diffuse, background shadowing increases, and new effects appear on the thermograms or the temperature and form of the heating curve change. Secondly, the non-decomposed part may move at the same speed together with the decomposition products. In this case the total chemical composition of the clay and colloidal fractions does not change or the changes are hardly noticeable. It is especially difficult to detect changes in chemical composition in fine-textured soils, since the products of decomposition move more slowly in them or stay in place. As we can see from Table 2 the chemical composition of the clay fraction of a fine-textured soil from the Moscow Oblast' changes little with depth, even though morphological indices and the data on the texture and chemical composition of the soil as a whole leave no doubt that podzolization and the decomposition of clay minerals take place in this soil.

It is easy to imagine such a case when a soil, in which clay and colloid move without being decomposed, could be mistakenly related to podzolized soils. Let us assume that a soil contains two minerals differing sharply in this dispersion and chemical composition, such as montmorillonite and kaolinite. The first mineral, being more hydrophilic and more finely dispersed, would move more easily downward, while kaolinite, being coarsely disperse and hydrophobic, will stay in place. As a result, montmorillonite will be concentrated at a certain depth, while kaolinite will be found above it. Since the $SiO_2:R_2O_3$ ratio in montmorillonite is equal to 4 and in kaolinite it is equal to 2, the total chemical composition will show a noticeable difference in the content of silica and aluminum at various depths, even

Table 2

Total chemical composition of the soil as a whole and of the fraction < 0.001 mm in diameter, % of ignited sample

Soil	Horizon and depth, cm	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	$\frac{SiO_2}{R_2O_3}$	Part. <0.001 mm in diam. %
Sod-podzolic on boulder clay loam, Snegiri, Moscow Oblast'	A_1 0—10	80,1	9,71	3,08	0,58	1,37	1,99	0,88	11,6	12,4
	A_2 29—37	81,0	9,51	3,73	0,54	1,22	1,93	0,85	11,3	13,4
	B_1 39—47	78,6	11,7	4,17	0,45	1,32	1,98	0,77	9,3	19,8
	B_2 48—56	76,7	11,6	4,83	0,59	1,54	2,00	0,77	9,0	22,2
	B_3/C 100—110	74.5	13,2	5,93	0,59	1,61	1,77	0,71	7.4	33,9
Same, fraction <0.001 mm in diameter	0—10	54,9	26,8	12,1	0,97	2,50	2,30	0,22	2,69	—
	29—37	54,3	26,2	13,3	0,90	2,52	2,44	0,22	2,65	—
	39—47	53,1	26,0	13,9	0,84	2,81	2,04	0,18	2,61	—
	48—56	53,8	27,5	13,9	1,03	2,83	1,05	0,16	2,49	—
	100—110	55,2	28,5	11,9	0,32	2,75	1,85	0,16	2,62	—

Note: Comma represents decimal point.

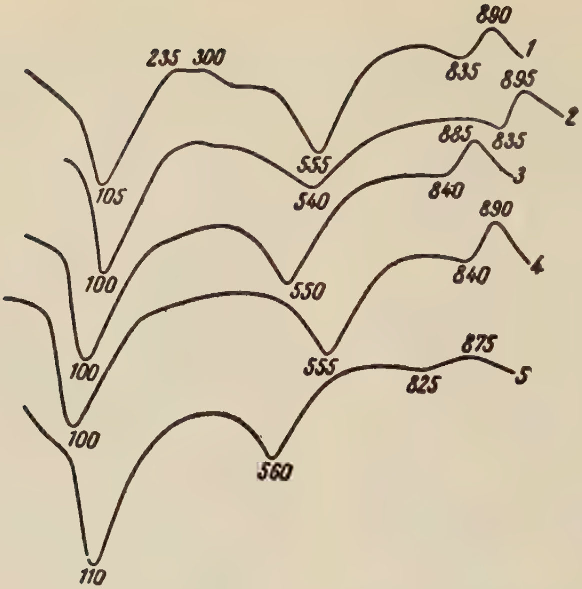

Fig. 2. - Thermograms of fractions < 0.001 mm in diameter, separated from sod-podzolic soil. Sod-podzolic soil on a moraine, Snegiri, Moscow Oblast'.

though it is caused by the movement of minerals of varying chemical composition without decomposition. We have often obtained thermograms which showed that montmorillonite moves more rapidly than other, less disperse minerals.

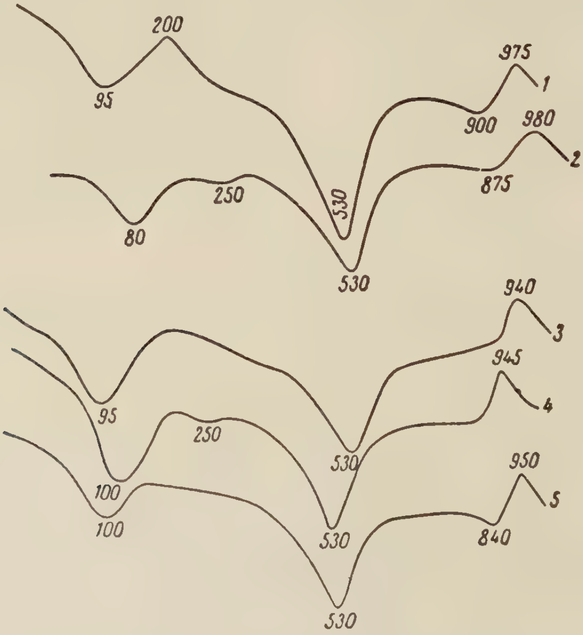

Fig. 3. - Thermograms of fractions < 0.001 mm in diameter, separated from brown forest soils of the Krasnodar Province.
A - Profile 5A. Brown forest soil on clayey shale. 1-4-12 cm; 2-110-120 cm. B - Profile 1373. Brown forest soil on shaly clay. 3 -2-10 cm; 4 -20-26 cm; 5-110-120 cm.

It is not always possible to detect a difference in the mineralogical composition of clay and colloids removed from various depths in sod-podzolic soils, since the thermographic and X-ray methods are not quantitative yet. To illustrate the foregoing, we present several thermograms of the clay fractions of a soil from the Moscow Oblast' (Fig. 2). The thermograms are similar for all depths of the profile and indicate the presence of minerals of the montmorillonite groups with an admixture of hydromica, amorphous substances, and, possibly, a small admixture of kaolinite. Only the thermogram of the sample taken at a depth of 100-110 cm differs somewhat in that hydromicas predominate in it, which is possibly associated with a different mineralogical composition of the parent material.

Since the decomposition products of minerals and the decomposition of plant residues (R_2O_3, SiO_2, and their mixtures) are usually amorphous, they can be detected by a combination of mineralogical and chemical methods. Amorphous substances give a thermal effect at 100°C on the thermograms because of the separation of hygroscopic water. Amorphous substances increase background shadowing on X-ray photographs. These features must be taken into consideration when judging the decomposition of minerals. The chemical method must also be used. As we know, the solubility of non-silicate sesquioxides and amorphous silica is higher than that of crystallized minerals (13, 14, 15).

Among the common solvents we can name the Tamm, Deb, and Jackson reagents. Our investigations showed that the Tamm reagent dissolves only part of the non-silicate sesquioxides. If three consecutive extracts are made, amorphous sesquioxides dissolve almost completely. The crystalline forms of sesquioxides hardly dissolve and they can be detected thermographically and partly by the X-ray method (13). To illustrate this, let us show you several thermograms (Fig. 3) of clay fractions extracted from brown forest soils of the Krasnodar Province (samples of A. I. Romashkevich). We can make certain important conclusions on the basis of these thermograms, as well as from X-ray patterns and chemical analyses which we do not include here. First of all the decomposition of minerals takes place in both soils. This is evidenced by the characteristic endothermal effect of crystalline sesquioxides at 250°C in samples at a certain depth and its absence in samples taken from the surface. The non-silicate sesquioxides found could have formed only as a result of the decomposition of minerals. Secondly, the mineralogical composition of the clay fraction differs over various parent materials. Minerals of the montmorillonite group, as well as an admixture of hydromica and amorphous substances, predominate in Profile 5A. Judging by the sharp thermal effects in the region at 530°C and 940°-950°C, kaolinite is present in Profile 1373, while montmorillonite mixed with hydromicas (effect at 840°C) is present at a depth of 110-120 cm. The presence of the latter minerals at a depth of 110-120 cm can be explained by the iluviation of highly disperse minerals from above. Certain investigators believe that new minerals form in situ at a certain depth, i. e., as a result of internal weathering (40). It is possible that both processes take place simultaneously.

An important sign of the movement of clay and colloids in soils is the presence of silica powdering at the surface of aggregates. The A_2 horizon of podzolic soil has probably the same mineralogical composition as the powdering which is found in podzolized chernozems, gray forest soils, solonetzes, and solods.

Various opinions are found in the literature on the genesis of the powdering and whitish horizons (6, 11, 12, 20, 22, 33, 36, 37, 39, 47, 49). In his last works, Glinka (11) expressed the belief that the whitish powder consists primarily of quartz and is the result of the removal of colloids and suspensions into underlying horizons. Gedroyts (7) explained the formation of the powdering by the decomposition of the adsorption complex and the subsequent removal of the decomposition products, whereby he thought that the agent of decomposition in acid soils is hydrogen, while in solonetzes it is sodium. Having studied the powdering in solodized soils, Tyurin (47) came to the conclusion that the explanation of Gedroyts is inadequate, since in addition to the chemical decomposition of the soil, silica accumulates at the expense of phytolitharia, i. e., silicon bodies forming in plants.

In the opinion of Zonn (22) and Remezov (36, 37) the powdering on the faces of structural units forms as a result of the decomposition of forest litter and the release of silica in the form of phytolitharia contained in plants. Rode and Feofarova (38) studied the mineral composition of the powdering in forest-steppe soils in detail and found that it consists primarily of quartz, feldspars, and clay aggregates. In addition, it contains admixtures of other primary minerals and phytolitharia.

In summarizing the foregoing views we may conclude that silica powdering consists primarily of quartz and other primary minerals. At the same time it contains amorphous silica (usually in small amounts), which is the result of its biological deposition, in particular, by phytolitharia.

We investigated the mineralogical composition of the podzolic and solodized horizons of various soils (Table 3). At the same time we made alkaline extracts (according to the Gedroyts method) in which we determined silica and alumina. Since not only amorphous silica, but partly crystalline silica are dissolved in alkaline extracts, we also made extracts from amorphous silica, certain minerals, and quartz (ground to various degrees) (Table 4).

Certain conclusions can be made on the basis of data presented in Table 4. Firstly, amorphous silica dissolves more readily than quartz. The solubility of quartz in alkali depends greatly on the degree of dispersion and reaches values which are considerably higher than those obtained when determining amorphous silica in soils by the Gedroyts method. The solubility of clay minerals in alkali is close to that of ground quartz. Marine algae may contain up to 50% silica which is removed in

Table 3

Mineralogical composition of whitish horizons and powdering according to microscopic data

Objects of investigation	Mineralogical composition
1. Whitish horizon of podzol on granite eluvium. Yakutia	Quartz predominates, other primary minerals are present, and there is some phytolitharia and clay
2. Same from strongly podzolic soil. Iksha, Moscow Oblast'	Quartz predominates, there is little phytolitharia and clay
3. Same from strongly podzolic soil. Yartsevo, Smolensk Oblast'	Quartz predominates
4. Powdering from solodized solonetz. Shadovsk	Quartz predominates, admixture of orthoclase, phytolitharia, and clay particles are present
5. Powdering from solod. Khartobad', Hungary	Quartz predominates, there is a considerable amount of phytolitharia

Table 4

Solubility of quartz, amorphous silicon oxide, minerals, and soils in 5% alkali, according to the Gedroyts method

Substance	Found in the extract in % of sample		Ratio of sample to solution
	SiO_2	Al_2O_3	
1. Quartz, grains 1-0.2 mm in diameter	1,4	—	1 : 100
2. Quartz ground for 1 hr.	3,98	—	1 : 100
3. Same, ground for 3 hrs.	8,93	—	1 : 100
4. " "	8,43	—	1 : 20
5. Amorphous SiO_2	88,2	—	1 : 20
6. Montmorillonite (askanite)	1,66	—	1 : 20
7. Muscovite, particles 0.1-0.5 mm in diameter	0,58	—	1 : 20
8. Kaolinite	1,23	—	1 : 20
9. Powdering from solod. Shadovsk	1,77	0,16	1 : 20
10. Powdering at the surface of solodized solonetz. Skadovsk	0,82	0,14	1 : 20
11. Powdering in solod. Askaniya-Nova	1,89	0,29	1 : 20
12. Strongly podzolic horizon. Podushkino, Moscow Oblast'	1,30	0,48	1 : 20
13. Podzol on granite, A_2 horizon. Yakutia	0,49	0,22	1 : 20
14. Strongly podzolic, A_2 horizon, Profile 6, Smolensk Obl'.	1,72	0,42	1 : 20
15. Suspension of marine algae, sample No. 17	46,6	1,03	1 : 20
16. Marine clay, fraction <0.001 mm in diameter	5,40	2,18	1 : 20
17. Solubility of silica gel in water at 50°C, accord. to Ayler	0,02	—	
18. Same, quartz at <150°C	Insignificant	—	
19. Same, quartz at >150°C	0,004	—	

Note: Comma represents decimal point.

an alkaline solution (sample No. 17).

The whitish powdering in solonetzes and solods contains an insignificant amount of amorphous silica and therefore there is less of it in the alkaline extract than in an extract of ground quartz, algae, marine clay, and, especially, in an artificial preparation of amorphous silica. Consequently, if amorphous silica or phytolitharia are present in the powdering, it is difficult to determine their amount by means of extracts. It is better to use the microscopic method or this method in combination with chemical and thermographic methods for this purpose. In light of the foregoing data the powdering and the whitish soil horizons are an evidence of clay removal.

Lysimetric investigations are of great importance for the detection of the decomposition of minerals. As we know, Vil'yams (6) determined the formation of various organic acids and their movement in soils by lysimetric investigations. Later, lysimetric investigations were used for various purposes (17, 18, 37, 43, 54, and others). By studying true and colloidal solutions entering the lysimeter we can determine

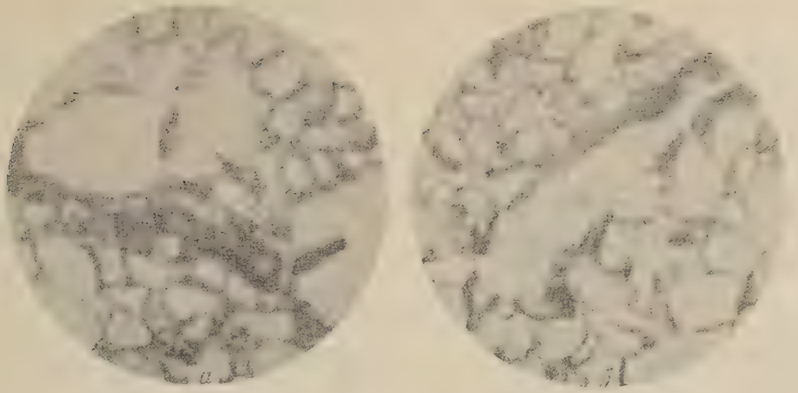

Fig. 4. - a - mobile polarizing clay filling the pores. Strongly podzolic, sandy loam soil. Zvenigorod Biological Station (magnified 70 times, nichols 11); b - mobile, polarizing clay on the walls of the pores, B_2C horizon, 92-102 cm, strongly podzolic, sandy loam soil. Zvenigorod Biological Station (magnified 70 times; nichols 11).

the number of substances moving in the soil during a given time interval, their chemical composition and the form of the compounds.

Smirnov's (43), and Gradusov's and Dzyadevich's (17) analyses of lysimetric solutions, obtained from strongly podzolized sandy loam soil under green moss pine forest (Biological station of Zvenigorod, Moscow State University), showed that the movement of sesquioxides in this soil takes place primarily in the form of very highly disperse organo-mineral colloids. The migration rate of individual elements, expressed in weight percentage relative to the total content in the soil, follows the series:

$$K > Ca > Mg > Si > Fe \approx Al$$

The large amount of sesquioxides and silica entering lysimetric solutions indicates that alumino-silicates are being decomposed. This is also evidenced by the fact that the amount of hydromica decreases and that of kaolinite increases in the clay fraction of the soil. Thermographic and X-ray investigations, as well as the insignificant amount of total potassium serve as certain proof of the decomposition of hydromica.

Polarizing clay, the coatings of which are visible on the microphotographs (Fig. 4), moves at the same time as minerals are being decomposed. Consequently, the removal of colloids and clay in strongly podzolized sandy loam soil is accompanied by the decomposition of minerals, as pointed out by K. D. Glinka, K. K. Gedroyts, and others.

Conclusions

1. Colloids and clay move in the soil in the form of mineral, organo-mineral, and organic compounds. The sources for the formation of colloids and clay are primary and secondary minerals as well as the decomposition products of plant and other residues of a biological origin.

2. As clay and colloidal fractions move, secondary (highly dispersed) and primary (slightly dispersed) minerals are being decomposed. Decomposition takes place in several stages, starting with dissolution, the replacement of the ions of the crystal lattice with the ions of the solution, and ending in the formation of amorphous and crystalline oxides.

3. The movement of colloids and clay is determined by the presence in the horizons, rich in colloids and clay of soils developed on homogeneous parent material, of concretions, ortstein, ortsand, silica powdering, and other new formations. In certain cases the soil is being enriched with clay and colloids as a result of their formation in situ.

4. The rate of decomposition and transformation of minerals depends on their crystallochemical nature, dispersion, and climatic and biochemical conditions under which weathering and soil formation take place. The opinion that primary minerals are less stable than secondary minerals is erroneous.

5. The signs used to determine the movement of colloids and clay with and without their decomposition, such as the presence or absence of polarizing clay, and the homogeneity or heterogeneity of the mineralogical and chemical composition, are not always reliable.

6. To determine whether the movement of highly dispersed minerals is or is not accompanied by their decomposition we must determine non-silicate sesquioxides and amorphous silica in soils and lysimetric solutions. It is expedient to accompany these determinations by investigations of the particle-size, mineralogical, and chemical composition of soils as a whole and their highly dispersed fractions.

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CARBON:NITROGEN RATIO IN THE SOILS OF KAZAKHSTAN

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Many investigators have dealt with the carbon to total nitrogen ratio in soils. Tyurin (9, 10), Remezov (7), Konova (6), and Bolotina (1) obtained very interesting material for the major soils of the Soviet Union. Vinokurov (2) gave analytical data for Siberian soils, Rutskov (8) for the soils of Central Asia, and Grabarov (3), for certain soils of Kazakhstan. In addition, the author of this article (4, 5) established the difference between the C:N ratio in chernozems of Northern Kazakhstan, the Cis-Caucasus, the Trans-Volga region, and the foothills of the Trans-Ili Ala-Tau.

The foregoing authors emphasize that the problem of the carbon:nitrogen ratio is of great theoretical and practical importance. The carbon:nitrogen ratio serves as an index of the characteristics of one or another soil group. Moreover, Vinokurov (2) believes that the C:N ratio is more or less an index of soil quality. The same opinion is expressed by Grabarov (3) who indicates that "we can judge the availability of soil nitrogen to higher plants by this value."

The majority of the foregoing investigators came to the conclusion that the C:N ratio narrows from chernozem to the more southern chestnut and brown soils, and sierozems, and relate this phenomenon to the increasing dryness of the climate to the south. At the same time, C:N data, obtained by individual authors for one or another soil, differ greatly from each other. For instance, Remezov (7) gives an average value of 4.5 for the C:N ratio of sierozems; Grabarov (3) gives a much wider C:N ratio (7.11) for the same soils, while Kononova (6) gives 7.6 for light sierozems. In addition, there are great differences between the C:N value for virgin and old plowland. According to Vinokurov (2), virgin lands have a narrower C:N ratio than old plowlands, while Grabarov insists that "virgin soils always have a wider (C:N, A. D.) ratio than old plowland."

Consequently, we believe that the average C:N values obtained by us for the major soils of Kazakhstan will supplement the material available in the literature, in particular, the data of Grabarov (3). As we will see later, our conclusions and his do not always agree. We believe that one of the essential shortcomings in the work of Grabarov is that he combines chernozems and chestnut soils of northern and Central Kazakhstan with the chernozems and chestnut soils of the foothills of Tian-Shan and Altay mountains according to average C:N values. This is not expedient, since even though the foregoing soils belong to one and the same group, they occur under different natural conditions and, therefore, greatly differ from each other.

The present article is based primarily on analytical data collected at the Chair of Soil Science of the Kazakh State University (headed by us) as a result of the work of the members of the Chair of Soil Science, as well as that of students, when writing their papers. In addition, we used all the material published on the soils of Kazakhstan. Unfortunately, the material proved to be very limited. There are either no determinations of total nitrogen or these are very limited.[1] In most of the published works of Kazakh soil scientists, devoted to the characterization of the soils of Kazakhstan. Therefore, there are much less data for regions which we (and also the other members of the Chair) did not investigate. This is especially true of brown soils and takyrs.

We determined the mean arithmetic data on humus, carbon, and total nitrogen and the average C:N values separately for virgin soils (including those in the forest) and old plowland on the basis of the material collected on each soil variety. We derived these average indices for the upper soil horizons: for the sod horizons of virgin lands and the plowed layers of plowlands. Let us note that we considered only those lands which were plowed before the virgin land was reclaimed, i. e., prior to 1954, as old plowlands.

Certain soil varieties which are close to each other were combined into one group when analyzing the material. For instance, calcareous and solonetzic chernozems and calcareous and solonetzic dark-chestnut soils. We did this because the calcareous chernozems and dark-chestnut soils for which we have analytical material are at the same time solonetzic. Of the mountain soils we combined mountain-forest, gray forest, and podzolized chernozems into one group. We also combined into one group mountain soils and very humic and moderately humic chernozems.

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[1] As examples we can give you the book of D. M. Storozhenko "Soils of the small hills area of Central Kazakhstan," Izd. Akad. Nauk DazSSR, 1952; that of L. I. Pachikina and M. I. Rubinshteyn "Soils of the Kokchetav Oblast'," Izd. Akad. Nauk KazSSR, 1960; the article by K. Sh. Faizov "Soil and soil complexes of the lower reaches of the Emba and Sagiza Rivers." Tr. in-ta pochvovedeniya Akad. Nauk KazSSR, Vol. 8, 1958, etc.

The average data derived by us on the content of humus, carbon, total nitrogen, and the C:N ratio of the major soils of Kazakhstan are presented in Table 1.

We can see first of all from the data on virgin lands that the relation between carbon and total nitrogen in the zonal plain soils of Kazakhstan narrows from north to south, while that for mountain soils, the distribution of which is governed by vertical zonality, narrows with decreasing absolute elevation.

Dark-chestnut, non-solonetzic soils deviate somewhat from this general pattern. Their C:N ratio is somewhat wider than in slightly humic, non-solonetzic soils. This is attributable to the fact that the majority of non-solonetzic dark-chestnut soils of the plains of Kazakhstan are coarse-textured (they are found primarily along the Irtysh inlet of the West Siberian lowland, where coarse-textured soils predominate as we know). There are almost no fine-textured non-solonetzic dark-chestnut soils in Kazakhstan (except for foothill soils, which we have considered as a special group). Coarse-textured soils are poorer in nitrogen than fine-textured soils, so that their C:N ratio is wider.

Very humic, non-solonetzic and moderately humic solodized chernozems have the widest C:N ratio among the plain soils, while mountain-forest and gray forest soils and podzolized chernozems have the widest C:N ratio among mountain soils. Since all these soils are found in a relatively more moist climate than other soils, the fact, established by Tyurin (9, 10), Remezov (7), Kononova (6), Grabarov (3) and others, that the carbon:nitrogen ratio in soils narrows as the climate becomes drier is confirmed by our data.

As a result, the narrowest C:N ratio is found in brown soils. It widens slightly in sierozems and takyrs. This is attributable to the fact that sierozems, for which we have the corresponding material, are found primarily in the foothills, where the climate is more humid than where brown soils are found. As far as takyrs are concerned, unusually they contain little nitrogen, as we can see from the foregoing data, and therefore the C:N ratio in them is somewhat higher.

Our data generally agree with the material of earlier investigators, but there is no full agreement as far as mountain soils are concerned. According to our data the widest C:N ratio is found in mountain forest-steppe and mountain-forest soils and not in chernozems.

If we compare the chernozems of the northern part of the Republic with the chernozems of the Tian-Shan and the Altay mountains we find that mountain chernozems have, on the average, a narrower C:N ratio than plain chernozems, as we have already noted (4).

Solodized chernozems have the widest C:N ratio among the individual subgroups of plain chernozems, while leached chernozems have the widest C:N ratio among the subgroups of mountain chernozems.[2] Solonetzic chernozems, including calcareous-solonetzic chernozems, have the narrowest C:N ratio. This is directly related to climatic conditions, since leached and solodized chernozems are found in a more humid climate than typical chernozems, while solonetzic chernozems are located in a drier microclimate.

The C:N ratio of soils of the meadow group narrows somewhat from meadow, meadow-bog and meadow-chernozem soils to meadow-chestnut and meadow-sierozem, soils, but generally it is wider than in zonal soils among which they are found. Especially sharp differences in this respect are found in meadow-chestnut soils as compared to light-chestnut soils and in meadow-sierozems as compared to sierozems. The fact that the differences between these soils are sharper than between meadow-chernozems and chernozems, is attributable, in our opinion, to the following. The moisture conditions in the dry steppes and deserts in depressions, where these soils are found, differ more from those of the surrounding areas than in the chernozem belt.

Among saline soils the C:N ratio is somewhat wider in meadow solonetzes than in solonchaks and steppe solonetzes and widens considerably in solods and gray solodized soils. It is wider in these soils than in the majority of zonal soils. Here we can see again the direct relation between the C:N ratio and climatic and microclimatic conditions, since solods and gray solodized soils, which are found in depressions primarily under forest vegetation, develop under conditions of a more moist microclimate as compared to the other saline soils and the majority of zonal soils.

The C:N ratio narrows from north to south or with decreasing absolute elevation in old plowlands, as in virgin lands. This pattern is somewhat disturbed in old plowland, as in virgin land, because plowed non-solonetzic dark-chestnut soils have a wider C:N ratio than plowed slightly humic, non-solonetzic chernozems. This is attributable, as in the case of virgin non-solonetzic dark-chestnut soils, to their coarse texture.

As we can see from Table 1 the C:N ratio is in all cases wider in old plowland than in the corresponding virgin soils.

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[2] As we have mentioned earlier (5) there are no leached chernozems in the chernozem zone of Northern Kazakhstan. The chernozems with little effervescence which are encountered there are not leached, they are solodized.

Table 1

Carbon:nitrogen ratio in the soils of Kazakhstan

Soil		Average				No. of observations
		Humus	Carbon	Nitrog	C : N	
		%				
	A. Plain soils					
Very humic, non-solonetzic chernozems	Virgin land	10,93	6,33	0,593	10,6	4
	Plowland	11,65	6,76	0,610	11,1	12
Very humic solonetzic chernozems	Virgin land	10,83	6,28	0,615	10,2	7
	Plowland	10,25	5,92	0,568	10,5	6
Moderately humic, non-solonetzic chernozems	Virgin land	7,56	4,38	0,427	10,2	14
	Plowland	7,42	4,30	0,385	11,1	24
Moderately humic solonetzic and calcareous-solonetzic chernozems	Virgin land	7,13	4,14	0,434	9,5	17
	Plowland	7,46	4,32	0,404	10,6	16
Moderately humic, solodized chernozems	Virgin land	8,75	5,07	0,429	11,8	15
Slightly humic, non-solonetzic chernozems	Virgin land	4,73	2,74	0,290	9,5	8
	Plowland	4,52	2,62	0,254	10,3	11
Slightly humic, solonetzic and calcareous-solonetzic chernozems	Virgin land	4,91	2.84	0,336	8,5	14
	Plowland	4,74	2,75	0,298	9,2	5
Meadow chernozem	Virgin land	8,91	5,16	0,483	10,7	21
Dark-chestnut, non-solonetzic soils	Virgin land	3,46	2,01	0,197	10,1	18
	Plowland	3,07	1,78	0,167	10,6	23
Dark-chestnut, solonetzic and calcareous-solonetzic soils	Virgin land	3,78	2,19	0,307	7,1	24
	Plowland	4,07	2,36	0,287	8,2	23
Light-chestnut soils	Virgin land	2,21	1,28	0,195	6,5	28
Meadow-chestnut soils	"	5,18	3,01	0,294	10,2	17
Brown soils	"	1,20	0,69	0,112	6,2	8
Sierozems	"	1,13	0,65	0,099	6,6	21
	Irrigated lands	1,62	0,93	0,128	7,2	18
Takyrs	Virgin land	0,55	0,32	0,047	6,7	6
Meadow-sierozems	Virgin land	2,85	1,65	0,184	9,0	17
	Irrigated lands	2,51	1,46	0,160	9,1	7
Meadow and meadow-bog soils	Virgin land	5,95	3,45	0,326	10,6	31
Solonchaks	Same	2,26	1,31	0,175	7,5	8
Steppe and meadow-steppe solonetzes	"	2,63	1,52	0,202	7,6	26
Meadow solonetzes	"	5,57	3,23	0,420	7,7	18
Solods and gray solodized soils	Primary under birch stands	5,58	3,24	0,324	10,0	38
	B. Mountain soils					
Mountain-meadow soils	High-mt. meadow	15,92	8,76	0,772	11,3	11
Mountain-forest, gray forest, and podzolized chernozems	Primarily in mountain forests	9,59	5,56	0,478	11,6	48
Very humic and moderately humic chernozems	Virgin land	8,95	5,19	0,569	9,1	15
	Plowland	8,78	5,09	0,528	9,6	9
Very humic and moderately humic, leached chernozems	Virgin land	9,73	5,64	0,539	10,4	11
	Plowland	9,31	5,39	0.517	10,5	8
Slightly humic chernozems	Virgin land	5,19	3,01	0,398	7,6	9
	Plowland	4,48	2,48	0,283	8,8	14
Dark-chestnut soils	Primarily plowland	3,64	2,11	0,242	8,7	13

Note: Comma represents decimal point.

Our results, which indicate that the C:N ratio is wider in old plowland than in virgin land, agree with the data of Vinokurov (2), but differ drastically from the conclusions made by Grabarov (3), who states, as mentioned earlier, that old plowland must have a narrower C:N ratio than virgin land.

In doubting the data of M. A. Vinokurov, P. G. Grabarov writes:

"These data are somewhat unexpected, because microbiological processes develop when any soil is tilled and the number of bacteria increase sharply. When humus is destroyed, the bacteria exhale carbon dioxide, while they bind nitrogen in the cell plasma.

Thus, the C:N ratio must narrow when soil is tilled, and this is true in most of the cases" (3).

However, the author does not present any factual material in his article to substantiate this conclusion. Grabarov forgets that the grain crops, which are mostly grown in the non-irrigated old plowlands of Kazakhstan, take up nitrogen intensely. The amount of nitrogen taken up by them from the soil can hardly be replenished by the process described by the author. In this case we could conclude that soils do not need the addition of nitrogen fertilizers at all, which is not true, of course. A narrower C:N ratio is found in old plowlands under grass-arable rotation when legumes are grown. But, as we know, grass-arable rotation is very limited in Kazakhstan and is practiced only on individual farms. Legumes (primarily alfalfa) are widespread only in the south of the Republic on irrigated land, primarily sierozems. But, as we can see from the foregoing data, plowed (irrigated) sierozems have a wider C:N ratio than virgin sierozems.

We must add that our data, which indicate that the C:N ratio of plowland is higher (as compared to virgin land), fully correspond to the general conclusion that this ratio becomes wider in soils with a higher degree of wetting; thus, even if we exclude irrigation, moisture accumulates in plowed lands after tillage and, consequently, they have a generally higher moisture content than virgin land.

When comparing our C:N values for the individual soils of the plain regions of Kazakhstan with similar data for the corresponding soils of the European SSSR, we must note that a great majority of soils in the Republic have a narrow C:N ratio, which is again attributable to the drier climate of Kazakhstan as compared to that in the western regions of the Soviet Union.

In conclusion we may note that our average values for the ratio between the carbon and nitrogen content of various soils have no absolute significance. They may change later when more material is collected and new calculations are made. However, our data show a definite pattern in the change of the C:N ratio in various soils in relation to climate.

Thus, the conclusion of a number of investigators that the C:N ratio in soils becomes narrower with the increasing dryness of the climate is valid for the plain as well as for the mountain soils of Kazakhstan.

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WATER EROSION OF SOILS IN THE STAVROPOL' HIGHLANDS

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Soil erosion by water and wind is widespread in a number of regions of the Stavropol' Krae. Therefore, the members of the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, and those of the Forest Institute, Academy of Sciences, USSR, conducted complex soil erosion investigations in the Stavropol' Krae in the summer of 1958. The investigations were conducted primarily in the area of the Stavropol' highlands (Mikhaylov, Aleksandrov, Jursav, Petrov, Izobil'noye, and other rayons). The present paper presents data primarily on the water erosion of soils.

The natural conditions of the Stavropol' highlands differ considerably from those of other regions with widespread water erosion, such as the Volga or Central Russian highlands, and therefore the development of erosion processes here is also unusual. Precipitation in the Stavropol' highlands increases from the northeast to the southwest from 400-650 mm. Sixty to 80% of the precipitation occurs here during the warm period. In a number of regions investigated, 40% of the precipitation during the warm period is often in the form of downpours (1, 4). The literature mentions downpours yielding 100 mm of precipitation in 24 hr (4). Because of this, maximum surface runoff in the Stavropol' highlands and therefore the most intense soil erosion are associated primarily with downpour types of precipitation.

Strong winds, primarily from an easterly direction, are characteristic of the Stavropol' highlands. There are also winds of the mountain-valley type. The frequency of periods with strong winds during dry and hot weather in spring and summer often results in the damage of considerable areas under crop by dust storms (4).

The relief, lithology, and soil in the Stavropol' highlands are extremely varied. The most characteristic relief feature in the Stavropol' highlands is the widely distributed elevated plateaus with a number of plantation surfaces. These relief formations are due to the alternation of dense and loose rock, such as platy sandstone, limestone, marly sandstone with gypsum-bearing clays, clay loam, and sand. The elevated plateaus are asymmetrical: most often they form steep stepped slopes descending toward river valleys in the west, while in the east they gradually lower and change into a system of ridges extending far from west to east. The ridged relief is also typical of wide depressions (Kursav rayon). The ridged relief becomes less pronounced with distance to the east and the absolute elevation of the ridges decreases. The most dissected relief is found in the parts of the plateaus near rivers and in the upper reaches of rivers. The latter usually originate in catchment basins of the collecting type from fan-like ravines and gullies, reaching far into the plateau. Longer and gentler slopes are found in distribution-type catchment basins.

The ridges are sometimes complicated by a network of hollows. The hollows are often found along the narrow watersheds of the ridges, dissecting the ridges into smaller, second-order ridges. As a result of the alternation of dense and loose rock, the runoff hollows, from the smallest to the largest, often develop diagonally in the direction of the slope and not along the general slope. Because of the dissection of long slopes by diagonal hollows, the surface runoff along the slopes is often intercepted by the latter. Therefore, short runoff flow lines (from the watersheds to the drainage network) are characteristic of a number of geomorphological areas of the Stavropol' highlands. The long slopes are divided into a series of small slopes with local micro-watersheds. Because of the lithological structure, stepped slopes are widespread in the highlands; straight and convex-concave slopes are less frequent.

The soil of the Stavropol' highlands is represented by dark-gray forest soils, Cis-Caucasian and central Cis-Caucasian chernozems, chestnut soils, and small spots of residual solonetzes in places. The largest area is occupied by chernozems.

The distribution of the main soil groups in the Stavropol' highlands is governed by vertical zonality, "and their relative diversity and rapid change are determined by the dissection of the surface and the variety of parent material" (6).

We studied erosion primarily on the central Cis-Caucasian chernozems — leached, calcareous, solonetzic, and the so-called chestnut chernozems (chestnut-mycelial-calcareous) (3, 7). Observations showed that moderately thick chernozems are most common in the Stavropol' highlands. Moderately thick chernozems change most often into shallow chernozems on slopes of more than 6°. Shallow chernozems are sometimes found on 4° slopes. Undeveloped soils of the chernozem type are found on very steep slopes. They have a shallow profile, poorly defined horizons, no intermediate horizons, and a low humus content. The characteristics of their profile result on the one hand from a moisture deficiency, and on the other hand from natural geological erosion.

Judging by our observations, the role of exposure in soil formation becomes noticeable only on slopes of more than 4°. Under these conditions soils with a lower humus content and less leaching form on southern slopes. The role of exposure is more noticeable in the piedmont belt, where thick chernozems are found on northern slopes (even at 8°), and less humic, moderately thick and shallow chernozems are found on southern slopes (of the same grade). In addition to relief, the characteristics of the soil-forming parent material influence the thickness of the soil. Shallow soils or soils intermediate between shallow and moderately thick are found on dense rocks (limestone and calcareous sandstone), whereas moderately thick or thick soils are found on loose parent material (under the same relief conditions). The variety of soils within small areas is associated with changes in lithology. For instance, calcareous chernozems on limestone in the upper part of a slope may be replaced lower by calcareous chernozems on loose deposits, these by leached chernozems on clay loams and clays, solonetzic chernozems on the deluvium of Maykop clay, etc.

The texture of the soils is varied. Medium- and fine-textured clay loam and clay soils predominate. Solonetzic chernozems are the most fine-textured soils (Table 1). The study of the texture of soils on slopes showed that the texture of the soils usually becomes finer in the lower part of slopes, which is associated with the transport of the fine fractions of the soil material as a result of erosion.

The structural and aggregate composition of the soils (Table 8) shows that leached chernozem has the most favorable water-stable structure (87.2% water-stable aggregates). Calcareous chernozems have a pulverulent structure and a lesser percentage of water-stable aggregates (70.2%-56.2%).

Solonetzic chernozems have a fine lumpy structure and a rather high content of water-stable aggregates (68.2%).

As we can see from Table 3, leached and calcareous chernozems are the richest in organic substances (6.72%-11.63%), while the least amount of humus is found in solonetzic and chestnut chernozems (3.91%-5.82%).

We determined the degree of erosion by comparing the thickness of all soil horizons (A, B_1, and B_2) subject to erosion with the thickness of horizons which are not subject to accelerated erosion. We studied soil erosion by making geomorphological soil profiles on slopes of various shapes, steepness, and exposure, distinguishing between slightly, moderately, and strongly eroded soils (1).

As far as the resistance of chernozems to erosion is concerned, it is of the following order. Calcareous chernozems on dense rocks are most susceptible to erosion, next are calcareous chernozems on loose rock and solonetzic chernozems, and, finally, leached chernozems, which have the best structure.

As we can see from Table 4, the effect of exposure on soil erosion is considerably less pronounced in the Stavropol' highlands than in the more northern regions because water erosion in the Stavropol' highlands is governed primarily by downpour type of precipitation. Nevertheless, even under these conditions erosion is more intense on southern slopes than on northern slopes. Thus, for instance, erosion of calcareous chernozems is slight on northern slopes which are about twice as long as the southern slopes.

Let us examine the relation between soil erosion and relief conditions. The erosion of calcareous chernozems on dense rocks is slight where the slopes are 1°-2° and the length of the runoff flow lines is 100-200 m. Soil erosion increases from weak to strong at slopes from 4° to 6°, respectively, with the same length of runoff flow lines. The erosion of calcareous chernozems on loose rocks is slight on 400- to 600-m length slopes of 1°-2°. The slight erosion of leached chernozems under uniform relief conditions corresponds to the moderate erosion of calcareous chernozems on loose rocks and the strong and severe erosion of calcareous chernozems on dense rocks.

The degree of soil erosion is also directly related to the type of watershed (8). In particular, slight soil erosion in a distributing catchment basin corresponds to moderate erosion in a collecting catchment basin with the same slope length and steepness.

Soil material may not be transported beyond the limits of a slope when they are pronouncedly stepped, which is very characteristic of Stavropol'. The material is being removed from steep scarps and accumulates on the steps. Noticeable accumulation occurs when the surface slope changes by 3° as compared to the steepness of the overlying section of the slope. The nature of the erosion, transport, and deposition of soil material on stepped slopes has a number of other characteristics. When the steps are short and gentle as compared to the above-lying steeper slope sections, the material accumulates over the whole surface of the step. If the steps are relatively wide at a distance from the break in the slope, accumulation can be replaced by soil erosion. The greater the inclination of the steppe (terrace) surface, the shorter is the distance

Table 1

Particle-size analysis, %. (Analyzed by O. Ya. Yaminskaya and A. P. Kulakova)

Profile No., soil, and location	Horizon	Depth of sampling, cm	Hygroscopic moisture, %	Losses on treatment with HCl	Particle, diameter, mm					
					1,0—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	< 0,001
115. Non-eroded leached chernozem. Kursav rayon, Vorovskolesskoye village.	A_0	0— 4	4,01	2,28	0,3	11,1	29,1	9,1	18,1	30,0
	A	4— 14	4,20	1,84	0,4	13,1	28,5	7,1	18,5	30,7
	B_1	30— 40	3,38	1,56	0,3	8.3	27,5	10,3	15,4	36,6
	B_2	40— 50	3,02	1,46	0,3	8,8	28,7	8,4	14,0	38,3
	C	80— 90	3,15	1,38	0,3	5,4	28,0	9,7	15,6	39,7
31. Non-eroded calcareous chernozem. Mikhaylov rayon, "Temnoles-skiy" sovkhoz	A_{plowed}	0— 5	5,51	10,5	1,5	4.1	13,5	7,9	15,0	47,4
	A	12— 22	5,85	9,7	2,0	5,2	9,4	7,3	16,3	50,0
	B_1	33— 43	5,07	18,3	1,6	4,8	10,7	6,9	14,0	43,6
	B_2	56— 66	4,06	31,8	1,3	4,8	10,0	3,9	10,3	37,9
	C	80— 90	2,88	50,6	1,4	2,8	7,1	3,2	8,5	26,4
34a. Strongly eroded calcareous chernozem. Mikhaylov rayon, "Temnoles-skiy" sovkhoz	A_{plowed}	0— 5	5,30	9,5	1,4	16,8	16,1	12,8	31,6	11,7
	B/BC	12— 22	5,30	9,6	1,3	16,6	14,2	11,7	31,5	15,2
49. Non-eroded solonetzic chernozem. Mikhaylov rayon, Lenin kolkhoz	A_{plowed}	0— 6	5,06	5,55	0,5	5,4	9,7	4,3	15,7	58,7
	B_1	21— 30	5,24	5,32	0,3	4,9	8,4	7,8	15,7	57,5
	B_1	39— 49	5,43	5,63	0,3	5,7	6,1	8,2	17,0	56,9
	B_2	61— 71	5,44	5,82	0,4	8,5	4,9	5,7	16,2	58,3
	C	98—105	5,15	8,33	0,1	9,3	5,7	3,4	15,8	57,3
87. Chestnut chernozem with deposit. Izobil'noye rayon, "Moskovskiy" sovkhoz	A_D	0— 10	3,61	8,62	0,1	11,6	26,7	5,6	13,4	33,9
	A	15-- 25	3,69	9,79	0,1	9.8	26,4	9,5	14,5	29,9
	B_1	35— 45	3,65	7,67	0,1	10,0	25,8	10,5	11,9	33,0
	B_1	50— 60	3,65	10,36	0,1	11,4	28,5.	6,1	10,6	33,0
	B_2	70— 80	3,49	11,44	0,1	10,8	25,3	8,4	12,1	31,8
	BC	102—112	—	13,90	0,1	11,6	24,3	9,5	11,7	29,0

Note: Comma represents decimal point.

from the break of the slope where accumulation is replaced by erosion and the more intense is the latter. As a result, strips of eroded and deposited soils (Fig. 1), of varying thicknesses and varying moisture conditions, alternate on the slope steps. This creates large variations in the time when soils mature, and in the yield of agricultural crops on various slope sections within one and the same crop rotation field.

In evaluating the degree of erosion of various soils we must note that slopes with shallow soils on dense rocks, with undeveloped soils, and also with solonetzic soils, are most susceptible to erosion. Under these conditions, even slight erosion can remove the soil to the surface of dense bedrock or its gravel, or to the saline horizons, i. e., lead to a sharp decrease in soil fertility.

Analytical data (Table 3) showed that the humus content decreases considerably during erosion. With moderate erosion the humus content decreases by one-third while with strong erosion it decreases by half. There is no noticeable decrease in humus content in solonetzic chernozems under slight and moderate erosion, which is apparently associated with the fact that eroded solonetzic chernozems are plowed to the depth of the upper horizon, only slightly touching the underlying horizons.

To determine the relationships between areas with various degrees of soil erosion in plowed fields (plowed a long time ago and occupied by row and grain crops using ordinary agricultural practices), slope steepness and the length of runoff flow lines, we used profile data in our calculations. The analysis showed that from 20%-35% of the slope area is occupied by non-eroded soils on surfaces with

Table 2

Structural (numerator) and aggregate (denominator) composition of soils

Profile No., soil, location, and land use	Horizon	Depth, of sampling, cm	Diameter of aggregates, mm								% of water-stable aggregates
			> 10	10—5	5—3	3—2	2—1	1—0,5	0,5—0,25	< 0,25	
115. Non-eroded leached chernozem, Kursavskiy rayon, Vorovskolesskoye Village. Pasture	A	4—14	1,8 —	6,3 6,1	21,8 24	23,1 19,1	28,0 27,1	5,9 6,0	5,5 4,9	7,6 12,8	87,2
31. Non-eroded calcareous chernozem. Mikhaylov rayon, "Temnolesskiy" sovkhoz. Corn	A_{plowed}	0— 5	0,2 —	2,7 1,8	5,4 1,8	9,2 6,2	26,6 17,8	16,3 32,0	20,1 10,6	19,5 29,8	70,2
34a. Strongly eroded calcareous chernozem. Mikhaylov rayon, "Temnolesskiy" sovkhoz. Corn	A_{plowed}	0— 5	11.4 —	12,7 0,4	10,2 5,6	11,4 16,2	32,5 23,4	8,0 7,4	8,6 5,8	4,9 41,2	58,8
49. Non-eroded solonetzic chernozem. Mikhaylov rayon, Lenin kolkhoz. Fallow.	A_{plowed}	0— 6	35.5 —	32,9 16,5	16.6 8,3	5.4 2,7	4.5 24,8	1.4 9,0	1,6 8,8	2,0 29,9	70,1

Note: Comma represents decimal point.

an average inclination of about 3°. Slightly and moderately eroded soils predominate on such slopes. Maximum erosion occurs on slopes with an average inclination of more than 6°. Under these conditions 20%-40% of the slope area is occupied by strongly eroded soils. An increase in the length of runoff flow lines at average angles of inclination of 3° leads to an increase in the area occupied by moderately eroded soils. An increase in the length of runoff flow lines on 6°-7° slopes leads to a considerable increase in the area occupied by strongly eroded soils.

We also calculated the long-term soil erosion on slopes from the profiles. Its magnitude depends on the steepness, length, and shape of the slopes. Erosion reaches 700-800 m³/ha on straight and convex slopes of 3°, while it decreases to 350-500 m³/ha on stepped and concave slopes of the same steepness and length.

The great number of intense downpours in 1958 (Table 5) made it possible to observe the process of seasonal water erosion.[1] We used the method (of Sobolev) of experimental plots on slopes subject to erosion, measured the volume of erosion furrows in fields, and calculated the volume of the material removed per unit area (10). Erosion furrows were found in fields occupied by row crops, and on straight and convex slopes in the central part of the Stavropol' highlands.

As we can see from Table 6, the intensity of seasonal erosion is directly related to the steepness and length of slopes. The steeper the slope, the less length is necessary for the removal of the same amount of soil material, a fact which is confirmed by the data in Table 7.

The volume of material removed (soil erosion intensity) on stepped slopes is related not only to the steepness and length of the slope, but also to the relationship between the steepness of the section studied and that of the above-lying part of the slope. The smaller the surfact inclination becomes as compared to that of the above-lying part of the slope, the shallower are the runoff furrows and the less material is removed. When the surface inclination decreases by 25% the volume of

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[1] Under seasonal erosion we mean processes which take place within one season (in this case the summer of 1958) with intense precipitation.

Table 3

Humus content in the soils. (Analyzed by K. I. Vasil'yeva)

Profile No., soil, location, and land use	Horizon	Depth of sampling, cm	Humus, %
115. Very humic, non-eroded leached chernozem. Kursav rayon, Voroskolesskoye Village. Pasture.	A_0	0— 4	11,03
	A	4— 14	9,91
	B_1	30— 40	5,35
	B_2	40— 50	4,27
	C	80— 90	1,47
51. Moderately humic, non-eroded leached chernozem. Mikhaylov rayon, Stavropol' secondary farm. Corn.	A_{plowed}	0— 5	6,72
	A_{plowed}	5— 15	5,06
	B_1	25— 35	5,13
	B_1	45— 55	4,48
	B_2	100—110	2,19
56. Moderately humic, moderately eroded leached chernozem. Mikhaylov rayon, Stavropol' secondary farm. Abandoned land.	A_{plowed}	0— 6	5,35
	A	17— 27	4,11
	B_1	35— 45	3,82
	B_2	60— 70	3,03
	C	90—100	1,34
31. Very humic, non-eroded calcareous chernozem. Mikhaylov rayon, "Temnolesskiy" sovkhoz. Corn.	A_{plowed}	0— 5	11,63
	A	12— 22	11,23
	B_1	33— 43	7,69
	B_2	56— 66	4,26
	C	80— 90	3,46
31a. Very humic, moderately eroded calcareous chernozem. Mikhaylov rayon, "Temnolesskiy" sovkhoz. Corn.	A_{plowed}	0— 5	8,37
	B	15— 25	Not detd.
	BC	29— 36	5,32
	C	43— 53	3,88
34a. Very humic, strongly eroded calcareous chernozem. Mikhaylov rayon, "Temnolesskiy" sovkhoz. Corn.	A_{plowed}	0— 5	5,42
	B/BC	12— 22	4,84
49. Non-eroded solonetzic chernozem. Mikhaylov rayon, Lenin kolkhoz. Fallow.	A_{plowed}	0— 6	5,82
	B_1	21— 30	5,15
	B_1	39— 49	3,94
	B_2	61— 71	3,61
11. Moderately eroded solonetzic chernozem. Kursavskiy rayon, Lenin kolkhoz. Winter wheat.	A_{plowed}	0— 5	5,49
	B_1	20— 30	4,03
	B_2	52— 60	2,13
	BC	71— 78	1,65
8. Strongly eroded, undeveloped solonetzic chernozem. Kursavskiy rayon, Lenin kolkhoz. Pasture.	AB	0— 10	3,87
	C	25— 36	1,55
87. Chestnut chernozem with deposit. Izobil'noye rayon, "Moskovskiy" sovkhoz. Edge of a forest belt.	A_D	0— 10	3,91
	A	15— 25	4,05
	B_1	35— 45	4,08
	B_1	50— 60	3,54
	B_2	70— 80	3,11
	BC	102—112	1,35

Note: Comma represents decimal point.

Table 4

Relationship of the degree of soil erosion on relief conditions in the Stavropol' highlands

Soil	Northern exposure			Southern exposure		
	Degree of erosion	Slope steepness,°	Slope length, m	Degree of erosion	Slope steepness,°	Slope length, m
Calcareous chernozem on dense rock	1. Slightly eroded	1—2	100—200	1. Slightly eroded	1—2	100
	"	3—4	< 100	—	—	—
	2. Moderat. eroded	4—6	< 100	—	—	—
	3. Strongly eroded	4—6	100—200	—	—	—
Calcareous chernozem on loose deposits	1. Slightly eroded	1—2	400—600	1. Slightly eroded	9—12	100
	2. Moderat. eroded	4—6	400—600	2. Moderat. eroded	9—12	100—200
	3. Same	2—3	900	3. Strongly eroded	12—15	100—200
Solonetzic chernozem	1. Slightly eroded	2—3	200—400	1. Slightly eroded	1—2	600—900
		—	—	Same	2—3	200—400
Leached chernozem	1. Slightly eroded	4—6	200—600	1. Slightly eroded	3—4	400—600
	2. Moderat. eroded	4—6	> 900	—	—	—

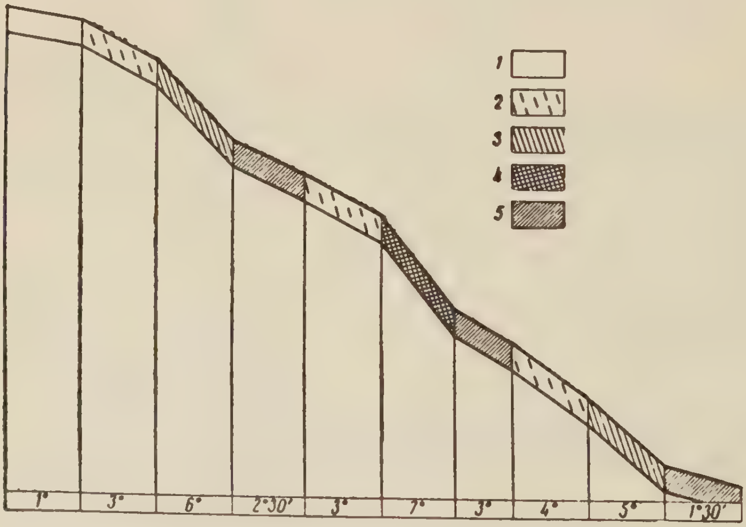

Fig. 1. - Distribution of eroded and deposited soils on a stepped slope. Soils: 1 - non-eroded; 2 - slightly eroded; 3 - moderately eroded; 4 - strongly eroded; 5 - deposited.

removed material decreases up to 40%.

The established principles of seasonal soil erosion indicate that erosion on slopes of more than 2° and a runoff distance of 400 m is very intense in years with very frequent downpours, especially in fields where row crops are grown along the slopes.

In addition to water erosion, most areas of the Stavropol' highlands suffer from soil deflation, which is especially intense in the upper parts of windward slopes. Chestnut soils, calcareous chernozems, and coarse-textured leached chernozems are subject to deflation most. We found that 20 cm of soil had been removed by long-term deflation (i. e. 2000 m³ of soil material per hectare) in the plowed areas of ridges located near watersheds and occupied by dark-chestnut coarse clay loams, in the Petrovsk rayon. A soil layer of 10 cm had been removed by deflation

Table 5

Number of downpours (with an intensity of more than 10 mm) in the various rayons of the Stavropol' Province from April 1 to September 1, 1958[a]

Rayons	April		May		June		July		August		Total from April 1 to September 1	
	Number of down-pours	Including > 20 mm	Number of down-pours	Including > 20 mm	Number of down-pours	Including > 20 mm	Number of down-pours	Including > 20 mm	Including down-pours	Including > 20 mm	Number of downpours	Including > 20 mm
Aleksandrov	—	—	1	—	5	1	4	1	1	—	11	2
Mikhaylov (Stavropol')	2	—	1	—	2	1	4	—	1	—	10	1
Kursavskiy	—	—	1	—	1	—	2	1	—	—	4	1
Petrov	1	—	1	1	2	1	3	—	—	—	7	2

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[a] According to the data of the Stavropol' hydro-meteorological serivce.

Table 6

Relationship of the volume of material removed to the steepness and length of slopes (calcareous chernozems)

Volume removed, m³/ha	Slope steepness, degree	Slope length, m	Slope steepness, degree	Slope length, m
<10	1—2	<500	—	—
10—100	2	>500	—	—
100—200	2°30′	500—800	5	<500
>200	3	>800	>5	500—800

Table 7

Indices of the relationship between the length of runoff flow lines and slope steepness at a volume of 100-160 m³/ha of material removed from calcareous chernozem

Length of runoff flow lines, m	Surface inclination, degree
400	2
300	2°30′
200	4
100	6
50	8

(also long-term) on calcareous sandy loam and coarse clay loam calcareous chernozem in the southern part of the same region. Deflated soils were found in a number of places in the Kursav, Nevinnoye, and other rayons.

Soils in the same areas are often subject to both deflation and erosion. Erosion control is especially complicated in such areas, in particular the selection of the orientation of windbreaks and water-regulating forest belts, etc.

Soil erosion is less intense (gully formation being very insignificant) in the Stavropol' highlands than under the same relief conditions in other eroded areas of the European USSR; this is attributable to the later development of accelerated erosion in the Stavropol' highlands as compared to regions of the central chernozem belt, for instance.

According to the investigations of Sudnov (12), the area of arable land in the Stavropol' Province has increased almost 3.5 times from 1896 to 1913, i. e., within 17 years. The area of arable land in 1958 was more than 4 times larger than in 1896. It must be considered that slopes of more than 5°-6° have been included in the category of permanent arable land only in the last 5 years, as a rule. Within approximately the same period the structure of the area under crops has changed in the following manner. In 1913, 1.5% of the area under crops was occupied by row crops, while the rest was occupied by grain crops. In 1958 row crops occupied 30% of the planted acreage. The plan for 1965 is to bring up the area under row crops to 40% of the planted acreage in a number of regions of the krae.

The young erosion phenomena in the

Stavropol' highlands forces us to pay special attention to land use. Unfortunately, little attention is paid here to relief and the nature of soil in the distribution of crop rotation fields, the direction of plowing and harrowing, and the distribution of row crops. Fields with row crops are very often located on steep slopes (8°-10° and more), while grain crops occupy relatively flat areas. The fields are usually plowed along the slopes. Soils, subject to deflation (calcareous chernozems and other coarse-textured soils), are often under pure fallow. This promotes deflation even during relatively weak winds. Because of this the first measures for the prevention of the further development of erosion must include the cultivation of row crops in flat areas, plowing across the slopes everywhere instead of along them, and sowing of deflated soils instead of leaving them under pure fallow. Since soil erosion in the Stavropol' highlands is primarily caused by the downpour type of precipitation, erosion control should not consist as much of additional practices (diking, harrowing, ridging, etc.). as in true soil cultivation under one or the other crop and crop rotation system, i. e. introducing farming systems developed by local krae agricultural institutions and applicable to the natural regions of the highlands (5, 9).

The arrangement of erosion-control forest belts in the Stavropol' highlands was not always sufficiently well thought out. The majority of forest belts, designed to break the wind, are dense instead of being open, they are often too wide (~20 m and more), and sometimes have the wrong orientation with respect to the prevailing winds.

In order that forest belts be effective, their structure and maintenance must be changed. At the same time one must not forget that for erosion control forest plantings must be combined with agricultural practices which promote the preservation of a good soil structure.

Conclusions

1. Water and wind erosion are widespread in the Stavropol' highlands and often occur together in one and the same areas.

2. In spite of the relative young age of accelerated erosion in the Stavropol' highlands, it already has caused considerable damage to agriculture. The amount of soil material removed over a long period from steep, plowed slopes by water erosion is 350-1000 m^3/ha, and that removed by deflation from comparatively coarse-textured soils is 1000-2000 m^3/ha.

3. The degree of soil erosion is closely related to the soil properties, the steepness and length of slopes, the types of watersheds, and the length of time the land had been reclaimed. The order of resistance of the soils of the Stavropol' highlands to erosion is the following: leached chernozems > calcareous chernozems on loose deposits and solonetzic chernozems > calcareous chernozems on dense rocks.

4. Depending on the shape of the slopes, the major portion of the soil material removed by water may either be transported beyond the limits of the slope (straight and convex) or be displaced and unevenly deposited within the limits of the slope (stepped slopes).

5. The study of the removal and redeposition of soil material with varying relief, lithology, and soils points to the necessity of considering these factors when investigating the problem of the genesis of soils.

There is no doubt that the removal, transport and re-deposition of soil material in areas with a dissected relief or areas subject to dust storms are of extreme importance in soil formation.

6. To prevent the further development of erosion in the Stavropol' highlands we must first of all: a) introduce protective crop rotation on slopes of more than 6°; b) remove row crops from steep, eroded slopes; and c) change the distribution of crop rotation fields in dissected relief to provide for soil tillage across slopes.

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CAUSES OF THE SUPPRESSION OF *AZOTOBACTER* IN THE NON-IRRIGATED SOILS OF CENTRAL ASIA

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Numerous microbiological soil investigations in Central Asia showed that the *Azotobacter* is absent or found in extremely insignificant amounts in automorphous desert soils which had not been irrigated for a long time (4, 8, 9, 11, 12, 13, 16, 17, 18, 20, etc.). Novogrudskiy and Mitrofanova (15) were able to find the *Azotobacter* in non-irrigated soils only by means of a special method. When irrigated, the same soils are a favorable medium for the development of the *Azotobacter*.

Our microbiological investigations of the non-irrigated virgin and old abandoned soils of the Murgab oasis of Turkmenia showed that by using ordinary methods of investigation it is impossible to find the *Azotobacter* in takyrs and takyr-like soils free of higher vegetation. It is sometimes possible to find the *Azotobacter* in takyr-like soils covered with ephemeral vegetation, but only in insignificantly small amounts: 1-4 cells/g of soil. At the same time, there are thousands and ten thousands of *Azotobacter* cells per gram of soil in the old irrigated takyr-like soils of the Murgab oasis.

It is believed that the main cause of such a severe suppression of the *Azotobacter* in non-irrigated desert soils is the extremely inadequate moisture regime of such soils (18). It is assumed that there are other causes which aggravate the unfavorable effect of the main factor: poor soil aeration, and the scant supply of organic matter to the soil. However, such an explanation is not exhaustive and does not agree with a number of important characteristics of the microbiological activity in non-irrigated desert soils.

The assumption that non-irrigated soil is extremely poor in moisture is not quite correct. Even in Southeastern Turkmenia, where the annual amount of precipitation rarely exceeds 100-150 mm, the soil moisture regime ensures rather favorable conditions for microbiological activity for a period of at least 2-3 months and longer in individual years (autumn-winter and spring are the wet periods) because of the very uneven seasonal precipitation distribution (70%-75% of the annual precipitation occur during the coldest period, from November to March).

We must emphasize that even though the non-irrigated soils of the desert zone are not rich in microbial population, they contain, as a rule, all the major physiological groups of soil microorganisms (4, 8, 13 etc.). As we know, even such moisture-loving organisms as soil algae can multiply in masses during the wet period of the year in certain desert takyr soils (2 and others).

We found hundreds of thousands and millions of cells of ammonifying and oligonitrophilic microorganisms, up to a thousand cells of cellulose decomposing aerobic microorganisms, up to a hundred cells of *Clostridium pasteurianum*, and hundreds and thousands of algae cells (per 1 g of soil) in samples of non-irrigated takyr and takyr-like soils taken in the Murgab oasis during the wet winter-spring period.

Thus, in spite of their unusual moisture regime, non-irrigated desert soils may contain peculiar and, during certain periods of the year, a quantitatively relatively rich microflora. However, even during the wet period of the year the *Azotobacter* is either absent in these soils or is found in insignificantly small numbers. Can we attribute this phenomenon to the fact that the *Azotobacter* cannot withstand the prolonged soil dryness during the dry period of the year, or to the fact that its requirements with respect to soil moisture conditions are very high? The answer to both questions is negative.

Our investigations of samples of old irrigated soils showed that the *Azotobacter* can endure it very well when the soil is kept dry for a long time (Table 1).[1] The unground and unsieved samples were kept at room temperature (from 5 °-32°C) in the dark in sterile jars with cotton stoppers. The moisture content of most of the samples did not exceed 1%-2% at the end of their storage under these conditions.

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[1] In our present work we assessed the *Azotobacter* in a medium of the following composition: 10.0 g sucrose; 0.5 g K_2PO_4; 0.5 g KH_2PO_4; 0.2 g $MgSO_4 \cdot 7H_2O$; 5.0 g $CaCO_3$; 20.0 g of leached agar, and 1000 ml irrigation water. Inoculation was deep, and the thickness of the layer of the medium did not exceed 3-4 mm. The assessment was made in 4 parallel Petri dishes.

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Table 1

Survival of the Azotobacter during the storage of soil sample

Sample No.	Duration of storage			Soil moisture, %		Azotobacter cells, 1000/g of absolutely dry soil	
	Years	Months	Days	Initial	At the end of storage period	Initial	At the end of storage per.
1		1	28	12,9	8,4	8,4	4,7
2		5	5	10,3	1,6	7,7	3,4
3		5	5	15,6	2,3	3,1	0,9
4	1	3	14	7,0	1,6	5,3	5,6
5	1	3	14	5,9	1,4	1,2	2,0
6	1	3	14	7,3	1,9	0,02	0,14
7	2	2	7	18,4	1,0	3,6	2,3
8	2	2	9	15,2	0,9	8,5	4,5
9	2	2	9	11,8	1,0	2,3	0,6
10	4	3	10	1,8	1,1	3,6	1,5

Note: Comma represents decimal point.

Table 2

Survival of the Azotobacter during prolonged storage of soil samples

Sample No.	Duration of storage		State of sample	Soil moisture, %	Azotobacter cells 1000/g of absolutely dry soil
	Years	Months		At end of storage period	
1	20	9	Not ground	1,05	0,76
2	17	9	"	0,68	0,15
3	20	9	"	0,98	0,23
4	20	9	Ground	1,71	0,002
5	20	9	"	1,67	0,000
6	20	9	"	1,40	0,002

Note: Comma represents decimal point.

We also analyzed samples of old irrigated soils kept in the laboratory for an even longer period of time (Table 2). We had no data on the initial number of Azotobacter cells in these soil samples. The results of analyses showed that after being kept under dry conditions for 17-20 years there were still hundreds of Azotobacter cells per gram of soil in the unground and unsieved samples. The Azotobacter disappeared almost completely from finely ground soil samples.

The foregoing data indicate that the Azotobacter survives well during the prolonged dryness of the soil. The high rate of survival of Azotobacter cells in soil kept from 2-4 years has also been noted by other investigations (1, 7, 9, 10, 24, etc.). According to the data of De and Boss (22) the Azotobacter survives very well in the soils of rice fields during dry periods, much better than certain other groups of bacteria and fungi.

We made special laboratory experiments to determine the possibilities for the development of the Azotobacter in soil with a low moisture content. We added a determined amount of water to air-dry soil (the soil was taken from fertilized, medium clay loam old plowland under cotton which was rich in Azotobacter cells; its full capillary moisture capacity was 34.9%). The experiment included treatments with soil wetting to 5%, 20%, 35%, 50%, 60%, 80%, and 100% of its full capillary moisture capacity against the following backgrounds: a) without the addition of energetic material, b) with the addition of ground cotton roots at a rate of 0.5% of the weight of the soil, and c) with the addition of 0.5% sucrose.

The soil was thoroughly mixed so that it would be evenly moist. The soils under all treatments received 0.1% of superphosphate. The experiment was made in porcelain jars with 250 g of soil. The experiment was repeated 3 times. The jars were kept in a thermostat at 25°-26°C. The water which evaporated from the jars containing soil with a moisture content of 5%, 20%, and 35% was not replenished after the experiment was started so as not to increase the moisture content of the upper soil layer and thus distort the results of the experiment. The other jars were kept at a constant moisture content by periodically adding water to compensate for evaporation. The jars were covered with watch glasses and wrapped in parchment paper; the loss of water within the first 12 days was small. The number of Azotobacter cells was determined after 3, 12, and 35 days. Since we are interested in the development of the Azotobacter under low soil moisture conditions, we give only the results of the experiment with the soil with a moisture content of 50% of full moisture capacity in Table 3. They show that the Azotobacter can develop noticeably under a rather low soil moisture level of 35% (as a result of the addition of cotton roots and sucrose) and 20% (as a result of the addition of sucrose). No propagation of the Azotobacter was observed at a soil moisture of 5% of full capillary moisture capacity. The possibility of the development of the Azotobacter at a soil moisture of 20% of moisture capacity was reported by Yenikeyeva (6).

Consequently, the Azotobacter can develop under such moisture conditions as are rather frequently encountered in non-irrigated desert soils during the wet autumn winter and spring periods. The moisture content in samples of non-irrigated soils of the Murgab oasis, taken during the cold period of the year, was quite often at a level of 10%-14% of the weight of absolutely dry soil. This level is undoubtedly sufficient for the development of the Azotobacter.

It follows from the foregoing that the sharp suppression of the Azotobacter in non-irrigated desert soils can neither be explained by the poor adaptability of the Azotobacter to prolonged soil drying, nor by its high requirements with respect to the moisture conditions of the medium.

The cause for the suppression of the Azotobacter must be related to the fact that the Azotobacter (or at least its strain which develops in southern soils) is an organism which requires relatively high minimum temperatures for propagation.

According to the data of Garder (3), the Azotobacter of Crimean soils could not develop and fix molecular nitrogen at temperatures from 10.0°-10.6°C. The very low nitrogen-fixing activity of Azotobacter strains (isolated from the soils of the southern United States), at 18°C was noted by Green (23).

Our investigations also showed that there is no noticeable propagation of the Azotobacter in the soils of Turkemenia at average daily temperatures below 11°-13°C. In addition to the material published earlier (5), let us give the results of another experiment, made in the winter of 1959.

Porcelain jars (12) were filled with 250 g of soil from old plowland under cotton, rich in Azotobacter. Ground cotton roots (0.5% of

Table 3

Development of the Azotobacter at different soil moisture contents

Moist.% of full capilry. moist. capacity	Azotobacter cells in 1 g of absolutely dry soils, in thousands																	
	Without the addition of organic matter						With the addition of cotton roots						With the addition of sucrose					
	Initial	Days of exper.			Aver. of 3 determinations	% of initial	Initial	Days of exper.			Aver. of 3 determinations	% of initial	Initial	Days of exper.			Aver. of 3 determinations	% of Initial
		3	12	35				3	12	35				3	12	35		
5	6,6	6,8	5,9	5,1	5,9	89	6,6	4,5	3,3	7,2	5,0	76	6,6	4,6	3,3	7,8	5,2	79
20	6,6	7,7	8,1	4,8	6,9	105	6,6	4,6	5,4	5,8	5,3	80	6,6	30,7	74,5	92,8	66,0	1000
35	6,6	6,2	6,2	5,0	5,8	88	6,6	24,6	14,5	12,1	17,1	259	6,6	114 000	74 100	42 400	76 800	1 1 63400
50	6,6	9,0	10,3	10,3	9,9	150	6,6	59,5	17,0	21,8	32,8	497	6,6	132 500	76 100	40 400	83 000	1 2 58000

Note: Comma represents decimal point.

soil weight) were added to 4 jars, 0.5% sucrose were added to another 4 jars, while no organic matter was added to the remaining jars (control). All jars received 1.1% of superphosphate. Two jars of each set were placed in a thermostat (at 25-26°C), while the rest of the jars were placed in a special box and buried 20 cm deep in the soil. The same soil moisture of about 60% of its full capillary moisture capacity was maintained in all the jars. The experiment was begun on January 1 and completed 37 days later on March 7. The temperature conditions in the soil at a depth of 20 cm during the experiment were: absolute temperature fluctuations from 2.0-10.5°C, average daily temperature fluctuations from 2.3-9.2°C, and an average daily temperature of 5.6°C.

As we can see from Table 4, the addition of cotton roots to the soil as well as sucrose, which is readily available to the *Azotobacter*, does not result in a noticeable propagation of *Azotobacter* cells at low temperature. At the same time, at a temperature of 25°-26°C the number of *Azotobacter* increased 6 times with the addition of cotton roots and several thousand times with the addition of sucrose. At low temperature other groups of soil microorganisms, such as oligonitrophiles and ammonifyers, multiplied noticeably.

Similar results were obtained in the other experiments made during the winter. In none of these experiments was there a noticeable multiplication of the *Azotobacter* at soil temperatures varying from 2-3°C to 10-13°C, usual for southern Turkmenia, under otherwise optimum conditions.

Such a reaction of the *Azotobacter* to temperature conditions explains in many ways the cause of its suppression in non-irrigated soils. The cause is the unfavorable combination of temperature and soil moisture conditions. In summer, as well as in late spring and early autumn, when the temperature conditions are favorable, the moisture deficiency does not allow the *Azotobacter* to develop in the soil. In winter, on the contrary, there may be sufficient moisture in the soil, but the lack of warmth interferes with the creation of the complex of conditions necessary for the development of the *Azotobacter*. Its life activity is possible only during a few days, or a week at most, in spring or more rarely in autumn, when there is precipitation during any part of the warm period. These few days are apparently sufficient to sustain the existence of the *Azotobacter* in the soil for many years. We must also keep in mind that precipitation in spring and autumn is usually accompanied by a considerable drop in temperature. However, a temperature increase during this period leads to the rapid drying of the soil.

Since there are very few *Azotobacter* cells in the soil, these microorganisms do not propagate sufficiently rapidly through the nutrient medium. This is particularly substantiated by our observations on the level of development of the *Azotobacter* during the first year of irrigation of new lands. At the end of the first year of irrigation the number of *Azotobacter* in such soils usually remains very low, from one to tens of cells per gram of soil.

In evaluating the conditions for the *Azotobacter* in the soils of the desert zone, we may note that many species and groups of soil microorganisms also develop well in winter, for instance in the soils of Southern Turkmenia. This was experimentally proved by us, particularly for the group of oligonitrophilic microorganisms (5). Many of the oligonitrophiles are the nearest competitors of the *Azotobacter*

Table 4

Development of the *Azotobacter* and other microorganisms at various temperatures

Temperature, °C	Organic matter added to the soil	Number of microorganisms at the end of the experiment (in 1000 cells/g of soil)						
		Azotobacter			Oligonitrophiles			Ammonifyers
		Replicate		Average	Replicate		Average	
		1	2		1	2		
2,3— 9,2	Control	12,3	12,8	12,6	31 900	61 500	46 700	110 000
	Cotton roots	8,8	13,1	11,0	232 000	141 800	186 900	20 000
	Sucrose	12,0	10,8	11,4	125 800	210 900	167 900	700 000
25,0—26,0	Control	7,1	11,8	9,5	26 800	32 600	29 700	25 000
	Cotton roots	50,2	62,4	56,3	129 000	150 800	139 900	25 000
	Sucrose	72 400	54 200	63 300	—[a]	—[a]	—[a]	250 000

[a] Because of the great development of the *Azotobacter* it was difficult to assess oligonitrophile colonies. Oligonitrophiles were assessed by the method of agar plates on a medium for *Azotobacter* as modified by Fedorova (21) using leached agar. The ammonifyers were assessed on peptone water by the titration method.

Note: Comma represents decimal point.

as far as sources of carbon nutrition under soil conditions are concerned, because they are closest to the *Azotobacter* in their requirements for nutrition conditions. The group of oligonitrophiles is very numerous in non-irrigated desert soils. These, as well as other microorganisms are apparently better adapted for multiplication under low temperatures than the *Azotobacter* and displace the *Azotobacter* from the number of active members of the biocoenosis of non-irrigated soils. Therefore, conditions for the preservation of *Azotobacter* cells in non-irrigated desert soils, which are periodically wetted during the cool period of the year, are probably much less favorable than in constantly dry soil samples kept under laboratory conditions, for instance. According to certain data (18), the *Azotobacter* may disappear from desert soils within 10-15 years after their irrigation is discontinued.

Other unfavorable conditions in non-irrigated and non-cultivated soils may play a certain role in the suppression of the *Azotobacter*. However, the *Azotobacter* develops well in non-cultivated, hydromorphic desert soils (1, 8, 10, 14, etc.) and does not develop in cultivated, but non-irrigated automorphous soils (1, 9, 11, 19, etc.). Consequently, the main cause of the suppressed condition of the *Azotobacter* cannot be the fact that a soil is not being cultivated.

Conclusions

The main cause of the suppression of the *Azotobacter* in non-irrigated desert soils of Central Asia (of an automorphous nature) is the prolonged unfavorable combination of their water and temperature regimes.

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IMPORTANCE OF PEAT IN THE CULTIVATED SANDY SOILS

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The utilization of coarse sandy and sandy loam soils in agriculture is of great importance to the national economy, since these soils occupy a tremendous area among arable lands in the RSFSR, Ukraine, the BSSR, the Lithuanian SSR, and other Soviet Republics. About 20% of the area under crops in the Ukraine is concentrated in the Polessiye zone alone. Sandy and sandy loam soils occupy more than 50% of the arable land in these areas, while in many farms all the arable areas are located on such low-productivity soils.

The low productivity of coarse soils is due to their low humus content (0.5%-1.5%), as a result of which they have an insignificant adsorption capacity, poor buffering, a high water permeability, and an unstable water and nutrition regime. In spite of the large amount of precipitation (550-700 mm), agricultural plants often lack soil moisture here.

To improve the water-physical properties of sandy soils they must first of all be enriched with organic matter — humus, which considerably increases their water capacity and the amount of available water to plants. This is evidenced by the data obtained at the Novozybkov experiment station of the All-Union Institute of Fertilizers and Agricultural Soil Science from 1949-1951 (Table 1).

As we can see from these data the amount of total and available water in the upper 60 cm of the soil in well-cultivated sands with an increased humus content of 1.3% is 54 mm or 540 m³ greater than in non-cultivated sands.

The systematic addition of organic fertilizers to sandy soils (manure, green manure) leads to a considerable increase in their productivity, a great accumulation of moisture in the root zone, and to its better utilization by plants. Thus, the following yields of individual agricultural crops were obtained at the Novozybkov experiment station during the extremely dry year of 1951, depending on the addition of organic and mineral fertilizers (Table 2).

The foregoing data indicate that under dry conditions the yield of all experimental crops was 3-6 times higher in plots to which organic fertilizers were added (manure and lupine) than in non-cultivated (non-fertilized) plots, while the loss of water per unit yield decreased 2-4 times under these conditions. However, as further investigations showed, the effectiveness of manure or lupine on well-aerated sandy soils increases considerably when they are used together with peat (Table 3). This is attributable to the fact that lupine (or manure) mineralizes rapidly and almost completely under conditions in sandy soils, while a large amount of the nutrients formed is leached by natural precipitation into the deep subsoil horizons which are unattainable by the root systems of field plants. If, however, they are added together with peat, the organic matter decomposes more slowly and the nutrients, which are gradually being released during this process, are more fully utilized by plants.

Taking the foregoing into consideration, long-term experiments were made at the experiment station in 1937 and 1940 to determine the influence of peat on the change in the water-physical properties and productivity of sandy soils.

The first experiment (started in 1937) was made in order to determine the effect of large amounts of clay and peat during the drastic melioration of loose sand in pine stand. The experiment was made against a background of 100 metric tons/ha of green lupine manure grown on the experimental plot and supplemented with green manure from other plots. The foregoing fertilizers were applied in the autumn of 1937 and placed at a depth of 18 cm under the first crop — winter rye. The effects and residual effects of the fertilizers added in 1937 to various crops were determined during the following years (except from 1941-1943).

The simultaneous addition of 400 metric tons/ha of peat against a background of lupine increased the yield of rye by 131%, that of oats by 118%, and that of alfalfa by 167% in the first 3 years as compared to the background. Peat had a high positive effect on the yield of perennial grasses even in the 9th year after it had been added, increasing the yield of hay by 50% as compared to the effect of lupine alone. The only crop on which peat had no positive effect was potatoes. This is attributable to the fact that the peat used in the

Table 1

Amount of water in sandy soil in relation to its degree of cultivation

Soil	Depth, cm	Bulk density, g/cm³	Wilting moisture, %	Moisture capacity of soil, %		Amount of water, mm/ha	
				by weight	by volume	total	avail. to plants
Unreclaimed sand with 0,4% humus	0—20 20—40 40—60	1,6 1,7 1,7	1,1 1,0 1,0	17,4 17,0 17,0	27,8 28,9 28,9	55,7 57,8 57,8	52 2 54,4 54,4
Cultivated sand with 1,3% humus	0—60 0—20 20—40 40—60	1,67 1,5 1,6 1,6	1,03 1,3 1,2 1,2	17,13 28,5 23,6 21,0	28,6 42,8 36,8 36,6	171,3 85,5 73,5 67,2	161,0 81,6 69,7 63,4
	0—60	1,57	1,23	24,4	38,3	226,2	214,7

Note: Comma represents decimal point.

Table 2

Influence of the long-term use of organic fertilizers on plant yield in the dry year of 1951

Crop	Yield, cntr/ha			Water loss per cntr/ha of yield, mm		
	Without fertilizers	With fertilizers	Productivity coefficient of fertilizers	Without fertilizers	With fertilizers	Productivity coefficient of fertilizers
Winter wheat	4,1	25,0	6,1	25,4	6,0	4,2
Potatoes	73,0	240,0	3,2	1,43	0.62	2,3
Buckwheat	4,0	13,0	3,2	26,0	11,5	2,3
Millet	8,0	23,0	2,8	13,0	6,5	2,0

Note: Comma represents decimal point.

Table 3

Influence of a 7-year use of alfalfa with peat on the yield of agricultural crops under rotation

Fertilizers used on fallow	Yield, cntr/ha		
	Winter wheat	Potatoes	Oat
Alfalfa (shoot)	18,7	143	12,6
Alfalfa + 40 met./ha of peat	21,4	215	15,4

Note: Comma represents decimal point.

experiment had a high calcium carbonate content (about 10%), which had a negative effect on the development and yield of potatoes.

The long-term positive effect of peat together with lupine is primarily attributable to the improvement of the physicochemical and moisture properties of sandy soil, which is evidenced by a sharp change in its water capacity: from 22.3% to 32.7%.

The single application of a large amount of clay in this experiment (614 metric tons/ha) did not have a positive effect and residual effect on the yield of the agricultural crops grown, in spite of the fact that the water capacity of the soil increased to 27%. This is associated with the high content of available aluminum which is detrimental to plants. The results of the experiment also indicate that the green manure of lupine, added without peat, is highly effective only on the first two crops (winter rye and oats) and has almost no residual effect on the yield of the following crops.

Table 4

Influence of clay and peat on the increase in the productivity of sandy soils

Experimental treatments	Relative crop yield, %					Moisture capacity of the soil in 1947, %
	1938, winter wheat	1939, oat	1940, alfalfa (hay)	1944, potatoes	1946, perennial grasses (hay)	
Control	100	100	100	100	100	22,8
Alfalfa, 100 met. t/ha(bkg).	242	221	147	122	130	23,1
Backgr. +614 met. t/ha of clay	227	192	141	131	135	27,1
Backgr. +400 met. t/ha of peat	373	339	314	130	180	32,7
Incr. produced by peat	+131	+118	+167	+8,0	+50	+9,6

Note: Comma represents decimal point.

Table 5

Influence of methods of peat application on the productivity of sandy soil

Experimental treatments	Relative yield, % of control				
	Alfalfa	Winter wheat	Potatoes	Spring grain crops	Perennial grasses
Control (bckgr. without peat $P_{90}K_{90}$)	100	100	100	100	100
Peat, 130 met. t/ha in the plowed layer	74	140	120	—	168
Same, 130 met. t/ha in a layer at a depth of 25 cm	95	144	120	127	247
Peat, 195 met. t/ha in the plowed layer	77	150	125	141	230
Same, 195 met. t/ha in a layer at a depth of 25 cm	98	158	125	162	246
Same, 130 met. t/ha in the plowed layer + 195 met. t/ha in a layer at a depth of 25 cm	83	167	138	170	266
Same, 2 lyrs: 195 met. t/ha at a depth of 25 cm and 130 met. t/ha at 30 cm	90	165	141	195	269

The second long-term laboratory-field experiment on the effect of peat layers (screened) on the productivity of sandy soils was started in the spring of 1940 in 3 green manure crop rotation fields. Consideration was given to the residual effect on the yield of various crops (up to 1953). The peat layers, 4-6 cm thick, were incorporated at a depth of 25 and 30 cm and their effect was compared with the effect of the same amounts of peat added to the entire plowed layer (0-18 cm). The actual amounts of peat were the same: 130 metric tons/ha of aerated peat (with a moisture content of 40%) for a 4 cm layer and 195 metric tons/ha for a 6 cm layer. The scheme and results of the experiment are presented in Table 5 in the form of average relative yields for all the years. As we can see from the data, the addition of peat sharply increased the productivity of sandy soil, having considerably increased the yield of grain crops (winter rye, oats, and buckwheat), row crops (potatoes), and especially that of hay from perennial grasses. Crop yield increased with increasing amounts of peat used.

Green manure crops (lupine and seradella) were an exception, their yield on peat decreasing somewhat as compared to the control. This negative effect of peat on green manure crops is attributable to the same cause as in the first experiment, i.e., the addition of a large amount of lime with the peat, which had a detrimental effect on the development of plants sensitive to it.

When added to the soil, peat has a definite positive effect on the water properties of sandy soils. Investigations of the water permeability of soils in plots where peat was mixed to the plowed horizon and added in the form of layers, showed that the latter lowers the water permeability of the soil. Thus, water from a 22 cm layer in the Doyarenko apparatus infiltrated into the soil within 16 min in the control plot, within 17 min in the plot where peat was mixed with the plowed horizon, within 22 min in the plot where peat was added in one layer at a depth of 25 cm, and within 24 min in the plow where peat was added in two layers.

Table 6

Influence of a peat layer on the moisture of sandy soil, % of dry soil

Layers, cm	During normal moisture conditions, June 12		During a dry period, August 18	
	Peat mixed with soil	Peat layer	Peat mixed with soil	Peat layer
0— 20	7,28	7,65	5,52	6,60
20— 40	5,88	7,87	3,17	3,21
40-- 60	6,05	7,95	1,76	2,30
60— 80	6,13	6,75	1,67	2,29
80—100	6,30	6,45	1,92	2,38

Note: Comma represents decimal point.

During the experiment with various methods of adding peat, observations were made on soil moisture during the period of wetting and the drought of 1951. The results of these observations (Table 6) showed that peat layers promote a higher accumulation and retention of moisture in the soil than peat mixed throughout the entire plowed horizon. The advantage of a peat layer is especially noticeable during the dry period in summer. Moreover, the maximum hygroscopicity of the soil treated with peat increased from 0.44% to 0.96%, while the full moisture capacity of the soil increased from 25% to 28.6%.

Observations on the development of the root system of plants showed that a large amount of fibrous roots, which run through the peat aggregates, forms in the peat zone.

In 1952 the Novozybkov experiment station developed a new effective method of using peat to sandy soils together with lupine. According to this method 40 metric tons/ha of peat are placed in small piles in winter on soil plowed in the autumn. These piles are scattered over the field in the spring and the field is sown with lupine. The peat with the lupine is then plowed into the soil in

Table 7

Influence of peat with alfalfa on wheat yield

Experimental treatment	Grain yield, cntr/ha
40 metric tons/ha of peat on pure fallow	12,0
Alfalfa for green manure	19,0
40 metric tons of peat applied to the surface in spring + alfalfa plowed under in aut.	21,4

Note: Comma represents decimal point.

Table 8

Effectiveness of the combined use of peat and manure on sandy loam soils in the "Komsomolets" kolkhoz

Fertilizers	Wheat grain yield, cntr/ha	Increment, cntr/ha
Without fertilizer	12,9	—
Peat, 36 met. t/ha	16,9	+ 4,0
Manure, 36 met. t/ha	23,1	+10,2
Manure, 36 met. t/ha + 24 met. t/ha of peat (mixture)	26,8	+13,9

Note: Comma represents decimal point.

autumn, two weeks before winter rye is sown. As the experiment showed (Table 7), such plowing creates an unusual peat-lupine humus in the plowed layer, which is very effective.

Peat has a positive effect when it is added with manure. This is evidenced by numerous experiments at the Novozybkov experiment station and production experiments at kolkhozes located on sandy soils. Thus, the simultaneous addition of two-thirds peat and one-third manure gave a higher rye yield at the "Komsomolets" kolkhoz, Novozybkov rayon, than when a full amount of manure was used (Table 8).

The higher effectiveness of the simultaneous addition of peat and manure, and peat and lupine is attributable to the fact that these mixtures decompose more slowly in sandy soils than manure or lupine alone, while nutrients are much better and more fully utilized by the plants.

Conclusions

1. The results of experiments on various methods of adding peat as a fertilizer showed that peat is a very important factor in the cultivation and increase of the total and effective productivity of coarse sandy soils.

2. The addition of peat, especially in conjunction with manure or with green manure of lupine improves the water properties of sandy soils, increasing their water capacity and decreasing their water permeability. This leads to a greater accumulation of moisture in the root zone of the soil and to its better utilization by plants.

3. A single application of a large amount of peat (130-195 metric tons/ha) ensures a considerable, long-term increase in the yield of all green manure crops. The greatest effect from increased amounts of peat is obtained when it is added in the form of a continuous layer at a depth of 25-30 cm without being mixed with the plowed horizon.

4. The simultaneous application of peat with manure or lupine to sandy soil enhances the effectiveness of the latter considerably, since the decomposition of the organic matter in manure and lupine is slower than with peat, while the nutrients, which are released during this process, are more fully utilized by plants.

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CHEMICAL AND MINERALOGICAL COMPOSITION OF CLAY FRACTIONS IN STRONGLY PODZOLIC SOILS IN CONNECTION WITH ELEMENT MIGRATION

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In this paper we discuss the results obtained from a combined investigation of the chemical and mineralogical composition of clay fractions, the composition of soil solutions, and the micromorphology of a strongly podzolic soil.

The subject of study was a soil under green-moss spruce-forest in a watershed plantation at Moscow University's Zvenigorod Biological Station.

Since the soil in question has already been described from many points of view in papers by staff members of the soil science faculty of Moscow University (6, 7), there is no need for us to say anything more about its formation and general properties than that the profile to be described has developed on a double-layer deposit. The humic-accumulative (A_1, 3-8 cm) and podzolic (A_2, 8-40 cm) horizons are formed from the top part of this deposit, represented by a coarse, silty clay loam. The illuvial horizon coincides with deposits of boulder coarse sandy loam.

The coarse silty clay loam is made up of poorly assorted and poorly graded grains of quartz, feldspars (microcline and plagioclase), and biotite. The heavy mineral fraction (specific gravity >2.75) consists of hornblende, zoisite, garnet, tourmaline, and zircon. Corroded phytolitharia often occur in the humic-accumulative horizon (Fig. 1, a and b).

In the boulder coarse clay loam the particles are better graded, the sandy fraction predominating, and more rounded; they are made up largely of quartz and granite fragments. In mineralogical composition it differs from the sandy loam in containing more quartz and less feldspar. The feldspars are often sericitized. The heavy mineral fraction is represented by hornblende, zoisite, garnet, tourmaline, and zircon (Fig. 1, c-f).

The similarity in the heavy fractions of the silty clay loam and the boulder sandy loam may indicate that the two deposits were formed from a single source. The mineralogical composition of the deposit and the roundstones is evidence that this source was the acid rocks of the Baltic crystalline shield.

Micromorphological investigation shows the humic-accumulative and podzolic horizons to be very impoverished in clay material (Fig. 1, a and b). Only in the bottom-most part of the podzolic horizon are there perceptible but small accumulations of free optically orientated clay, indicating that the washing out of fine soil suspensions has occurred. Sizeable segregations of optically orientated clay in the form of film near the primary minerals and of "sleeves" at their junctures can be detected in the illuvial horizon. Micropores and cracks in the B horizon are sometimes filled up with strongly polarized separations of free clay with punctuations of humic inclusions. The frequent coincidence of free clay with the channels of plant roots and the inclusion of organic matter in it are indications of a migration of fine clay suspensions in this soil.

The amount of mobile clay matter in the sample from the ortsand interlay was particularly large (Fig. 1, f). In comparison with the encompassing soil mass of the B_2C horizon the ortsand interlay is distinguished by its high content in silty and clay particles and its richness in oxidized iron compounds. The ortsand in this soil may well have formed as a result of the illuviation of iron compounds into a finer textured interlayer; the inwash of highly dispersed clay material also plays an important part in this.

Direct observation under the polarized microscope showed that there was very pronounced transport of iron compounds from the podzolic horizon. The iron brought up to the top from a depth of 40 cm combines with the "free" clay and organic matter separating in the form of intrusions in the pores and cracks of the illuvial horizon.

The total chemical composition of the colloidal clay fractions (Table 1) proved fairly uniform throughout the soil profile. The slight increase in the sesquioxide content at a depth of 60-70 cm as compared with the upper soil does not seem to be due to differences between the sandy loam and silty clay loam deposits, since the sesquioxide amount is found to diminish at a depth of 110-120 cm. This is presumably due to an influx of iron and

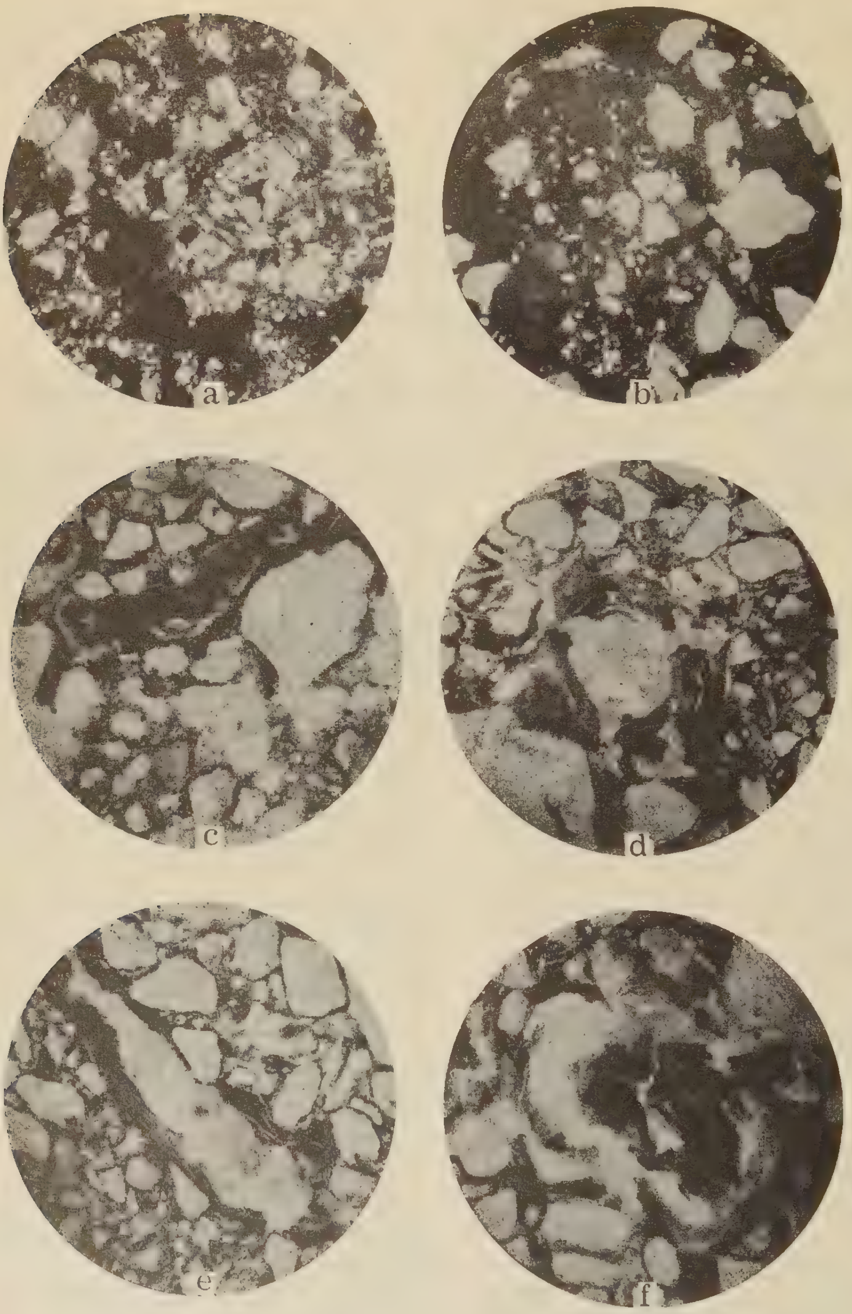

Fig. 1. - Microphotographs of plane-parallel thin sections (X 140) a - A_1 horizon, 3-8 cm; nicol +; b - A_2 horizon, 25-35 cm; nicol +; c and d - B_1 horizon, 60-70 cm; e and f - (ortsand interlayer) - B_2C horizon, 110-120 cm.

aluminum compounds during the process of podzol formation. The figures given in Table 2 support this. The peak content in "readily mobile gels" occurs in the sample from the 60-70 cm horizon, where the total aluminum and iron content is high. Lower down the profile the "readily mobile gel" content again decreases. The colloidal clay fraction of the ortsand interlayer is distinguished by its high iron oxide content.

The figures in Table 2 indicate that iron accumulation occurs in "readily mobile forms."

Table 1

Total chemical composition of the <0.001 mm diameter particles, % of ignited material

Horizon	Depth, cm	SiO_2	R_2O_3	Al_2O_3	Fe_2O_3	MgO	K_2O	$\frac{SiO_2}{R_2O_3}$	Exchng. capacity meq/100 g
A_1	3—8	55,3	36,5	31,9	4,6	2,8	0,5	2,7	46,3
A_2	25—35	55,9	36,1	31,7	4,4	2,0	0,8	2,7	47,5
B_1	60—70	55,4	38,2	33,5	4,7	2,2	0,6	2,4	51,0
B_2C	110—120	58,2	34,9	30,5	4,4	2,4	0,9	2,6	55,9
Ortsand	110—120	50,1	41,0	26,3	14,7	1,9	2,6	2,4	42,6

Note: Comma represents decimal point.

Table 2

Analysis figures for Tamm's extract from <0.001 mm diameter particles % of ignited material

Horizon	Depth, cm	SiO_2	Al_2O_3	Fe_2O_3	R_2O_3	Total
A_1	3—8	0,88	1,62	1,40	3,02	3,90
A_2	25—35	0,75	1,13	1,37	2,50	3,25
B_1	60—70	1,20	2,64	1,93	4,57	5,77
B_2C	110—120	1,06	2,36	1,13	3,49	4,55
Ortsand	110—120	1,48	2,20	9,50	11,60	13,08

Note: Comma represents decimal point.

The micromorphological observations discussed previously, together with the material on total chemical composition of the clay fraction and on the composition of the Tamm's extract from the clay fractions, constitute evidence of iron and aluminum loss from the podzolic horizon[1] as well as loss of clay matter. In the illuvial horizon the iron and, apparently, the aluminum form intrusions in the micropores and microcracks, along with "free" optically orientated clay and humic matter.

The fact that the clay material is undoubtedly mobile indicates that its mineralogical composition may well be uniform throughout the soil profiles; but we should expect the more highly dispersed clay minerals to move more readily into the lower horizons than the less dispersed ones.

Table 3 shows the values obtained from lysimeters over a period of two years. The element found in largest quantity in the soil solution was potassium (18 mg/liter); the elements present in smallest quantities were calcium (5 mg/liter) and magnesium (about 1 mg). There is a fairly high content in silica (8 mg) and alumina (4 mg). The soil solutions were poorest in iron (0.2 mg). The active reaction of the soil solutions was acid (pH 4.5-5.0). The content of organic matter varied from 10 to 100 mg/liter, the water samples from lysimeters from the deeper horizons containing the smallest quantities of organic compounds.

Proceeding from the total chemical analysis of the top (down to 40 cm) part of the soil profile given in one of our previous papers (2), and the average amount of each element obtained in the soil solution, we classified the elements in order of relative mobility as follows: K > Ca > Mg > Si > Al ≈ Fe.

The order of relative mobility of the elements, taken together with the data discussed above, indicates that all of the elements, including iron and aluminum, in the podzolized horizon of the soil described are highly mobile. The silicate silica is lost by the podzolic horizon. This bears out Rode's well known contention (5) that there is a relative accumulation of residual quartz in the A_2 horizon, with the result that it is difficult for new clay to form in this horizon (a conclusion recently reached by Barschad (8) by a different method), while the present composition of its silicate part is determined first by the initial mineralogical composition of the colloidal clay and secondly by consecutive or staged modifications of the clay minerals (13). The much higher mobility of silica as compared with the alumina indicates that these changes were in the direction of a relative accumulation of clay minerals with a narrower $SiO_2:Al_2O_3$ ratio. The high mobility

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[1] This reference is born out by the figures obtained by K. M. Smirnova for the soil profile described here (7, 6).

Table 3

Chemical composition of soil solutions of strongly podzolic soil[a], mg/liter

Depth of lysimeter, cm	Organic matter	Si	Al	Fe	Ca	Mg	K	Na	$\frac{SiO_2}{R_2O_3}$
				1958					
3	74,1	8,5	2,5	0,6	8,5	0,8	20,2	2,3	4,7
10	9,7	8,5	2,4	0,3	8,5	0,6	21,1	2,4	5,4
40	7,1	8,3	2,1	0,3	4,4	1,0	19,7	2,6	5,7
				1959					
3	48,5	10,4	4,2	0,1	4,2	2,1	16 4	4,1	3,7
10	16,1	6,3	3,1	0,1	3,4	1,4	14,4	4,5	3,3
40	7 8	5,7	2,2	0,05	2,2	1,3	17,6	3.3	4,0
Average over two growing periods		7,8	2,7	0,2	5,2	1,2	18,1	—	4,5

[a] Average determinations of the content of each element in samples taken in May, June, July, August, September, and October of each year (in duplicate).

Note: Comma represents decimal point.

of potassium, magnesium, and iron however indicates that minerals of the hydromica type are unstable. Moreover, the mineralogical composition of the colloidal clay in the podzolic horizon is due, as we have already noted, to the removal of highly dispersed suspensions of clay minerals. We may assume that of the clay minerals in podzolic soils, represented by montmorillonite and kaolinite, the former, being the most highly dispersed, will also be the one most intensively removed from the podzolic horizon. Both the

Table 4

Mid-band distances of orientated (by pressure) aggregates of clay fractions of strongly podzolic soils (FeK α radiation, t = 6h)

A_1 3—8 cm			A_2 25—35 cm			B_1 60—70 cm			B_2C_1 110—120 cm			Ortsand 110—120 cm		
Sample No.	d (Å)	I[a]	Sample No.	d (Å)	I	Sample No.	d (Å)	I	Sample No.	d (Å)	I	Sample No.	d (Å)	I
	(17,3)[b]			(16,8)			(17,18)			(17,3)			(17,4)	
1	14,78	6	1	14,86	6	1	14,46	7	1	14,98	7	1	14,79	4
2	7,23	6	2	7,19	5	2	7,10	4	2	7,21	4	2	9,81	4
3	5,08	2	3	5,11	2	3	5,21	3	3	5,12	4	3	7,11	3
4	4,52	3	4	4,58	4	4	4,66	2	4	4,60	4—5	4	5,69	5
5	4,28	4	5	4,36	6	5	4,14	5	5	4,46	5	5	4,95	3
6	3,56	3	6	3,61	2	6	3,52	3	6	3,48	2	6	4,48	6
7	3,31	9	7	3,27	7	7	3,30	6	7	3,26	8	7	4,23	3
8	2,72	5	8	2,61	4	8	2,81	4	8	2,65	3	8	3,69	2
9	2,54	1	9	2,49	1	9	2,53	2	9	—	—	9	3,41	9
10	2,31	2	10	2,40	3	10	2,36	4	10	2,40	3	10	2,68	7
11	2,12	4	11	2,18	5	11	2,21	2	11	2,18	2	11	2,43	2
12	2,00	3	12	2,04	2	12	2,12	2	12	2,04	2	12	2,00	3
13	1,85	5	13	1,86	5	13	1,78	4	13	1,74	4	13	1,80	3
14	1,68	6	14	1,74	4	14	1,65	4	14	1,61	4	14	1,65	3
15	1,51	3	—	—	—	15	1,57	3	15	1,55	3	15	1,50	4

[a] Visual intensity, 10-division scale

[b] Orientated sample saturated with glycerol

Note: Comma represents decimal point.

removal of clay mineral suspensions and their subsequent weathering are obviously processes making for similar results, namely an alteration in the composition of the clay fractions in the directions of lower potassium and magnesium content, a narrower SiO_2:Al_2O_3 ratio and a lower exchange capacity or, in other words, a relative accumulation of kaolin type minerals (1:1). Although probable in itself this hypothesis must be supported by the results of direct determinations of the mineralogical composition of the clay fractions and we shall now go on to consider these.

X-ray investigations of the clay fractions showed that all the samples were fairly alike in mineralogical composition (Table 4). The 14.5-15.0 Å, 4.5-4.6 Å, and 2.6-2.8 Å lines come out clearly on the X-ray photographs. The 17-18 Å reflection appears on saturation with glycerol, indicating the presence of montmorillonite. The peak amount of this mineral is found in the B_1 horizon. A kaolinitic mineral, which is the second component of the crystalline phase of the fractions <0.001 mm in diameter in the soil studied, can be identified from the mid-band distances 7.1-7.2 Å, 3.5-3.6 Å, and 2.3-2.4 Å. The largest amount of this mineral was found in the colloidal clay sample from a depth of 3-8 cm.

The X-ray pattern for the clay fraction separated from the ortsand interlayer show that its crystalline phase consists of at least three clay minerals. The basal reflection at 14.8 Å (17.4 Å with glycerol saturation) indicates the presence of a mineral of the montmorillonite group. A mineral of hydromica type can be identified at mid-band distances of 9.8 Å and 4.9 Å. The reflections at 7.2 Å, 3.6 Å, and 2.4 Å indicate the presence of a kaolinitic component.

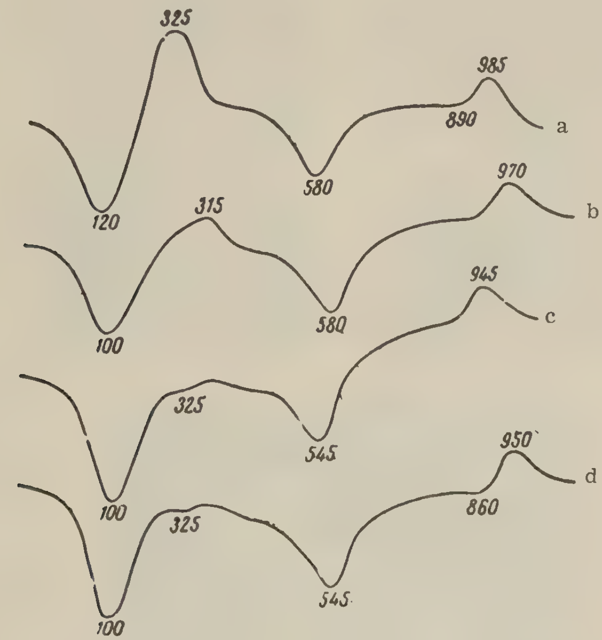

Fig. 2. - Thermograms of <0.001 mm diameter fractions (3 g sample treated with H_2O_2 rate of heating 10-12°C per min.)
a - A_1 horizon; 3-8 cm; b - A_2 horizon, 25-35 cm; c - B_1 horizon, 60-70 cm; d - B_2C horizon, 110-120 cm.

The results from thermographic investigations corroborated the conclusions previously reached on the basis of the X-ray data (Fig. 2). The endothermal effect at 100-120°C, which covers a considerable area, indicates the presence of a large quantity of hydrophilic compounds in the composition of the clay fractions. In the sample from the A_1 horizon these are represented by organic and organo-mineral compounds, in addition to the clay minerals, which are not destroyed by treatment with H_2O_2. This is borne out by the presence of a sizeable exothermal peak at 325°C. If, however, we allow for the low organic compound content in the clay fractions from the subjacent horizons, we must assume that the peak at 100-120°C is due to the presence of a mineral of the montmorillonite group. There is further evidence for this in the presence of an endothermal peak at 860-890°C. The smallness of the peak at 860-890°C, along with a certain sharpening of the effect at 550-580°C, indicates the presence of a mineral of

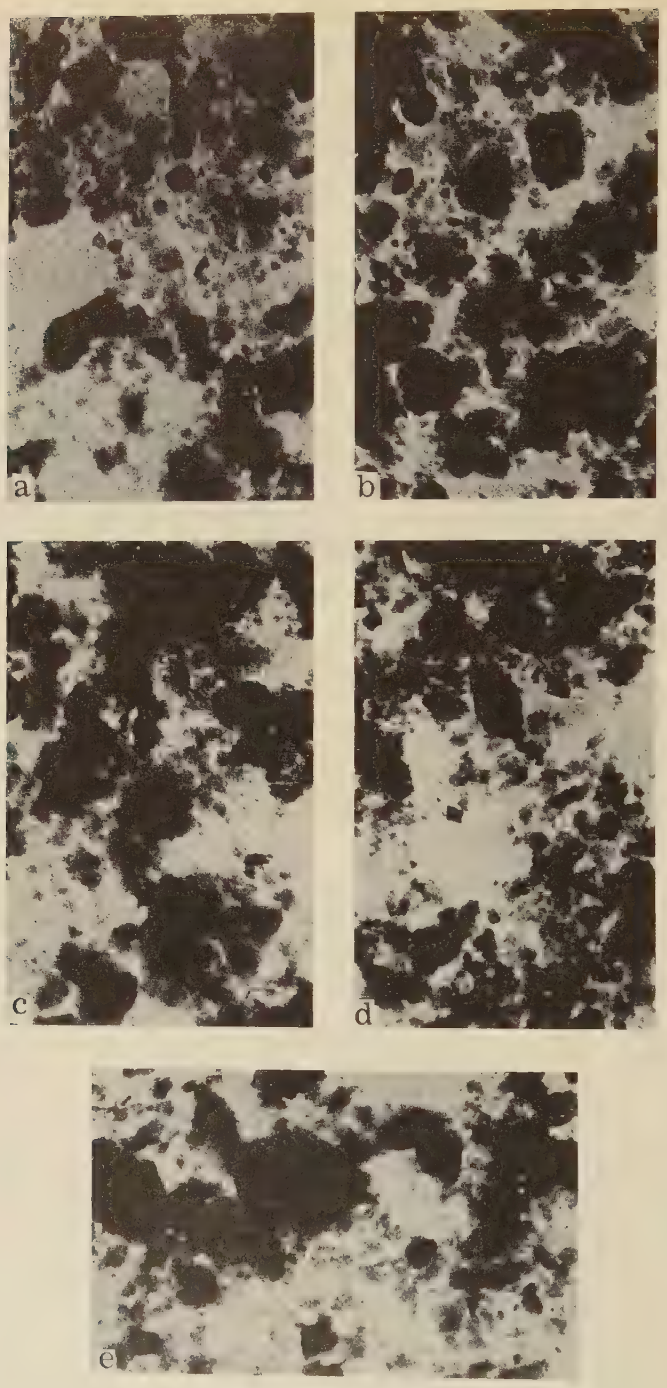

Fig. 3. - Electron-microscope photographs of <0.001 mm diameter fractions (X 1800, EM-3 instrument)
a - A_1 horizon, 3-8 cm; b - A_2 horizon, 25-35 cm; c - B_1 horizon, 60-70 cm; d - B_2C horizon, 110-120 cm; e - ortsand, B_2C, 110-120 cm.

the kaolinite group, and so bears out the X-ray findings. Since the second endothermal effect of the colloidal clay samples from the A_1 and A_2 horizons shifts into the high-temperature region we must assume that there is more kaolinite here than in the B_1 and B_2 horizons.

The presence of a slight endothermal effect at 300-315°C on the thermograms relating to the clay fractions of the samples from a depth of 60-70 cm and 110-120 cm indicates the presence of goethite.

Electron-microscopic investigations show that there are considerable quantities of particles of colloidal dimensions of the <0.001 mm in diameter (Fig. 3). Fragmental forms of clay minerals predominate. The electron microscopic results bear out the clay mineral determinations based on thermal analysis and X-ray data. The presence of montmorillonite in the form of compact articles measuring 1.0-0.5 μ with "eroded" edges (Fig. 3, c-e) was established from the electron microscope pictures. Fairly compact fragments of minerals, sometimes with an angle between the faces proper to kaolinite also enter into the composition of the colloidal clay fractions (Fig. 1, a, b). The transparent fragments of various shapes represent hydromicas (Fig. 3, c, e).

The values for the chemical composition of the clay (Tables 1 and 2) are consistent with the idea of a montmorillonite-kaolinite association of clay minerals in the colloidal fractions of the strongly podzolic soil. The $SiO_2:R_2O_3$ molecular ratios vary from 2.5 to 2.7 and the exchange capacity of the clay fractions does not exceed 55 meq. Both the chemical analysis and the X-ray investigation reveal the presence of considerable quantities of hydromica in the colloidal clay fraction from the ortsand interlayer. The values for the exchange capacity of the colloidal clay fractions are consistent with the X-ray and thermographic patterns, which showed the top part of the soil profile to contain kaolinitic mineral. Despite the presence of organic matter in the clay fraction with the A_1 horizon, exchange capacity proved lower than in the A_2 and B horizons.

The clay fractions of this strongly podzolic soil seem to consist mainly of montmorillonite and kaolinite. Apart from the clay minerals, goethite and "readily mobile gels" of sesquioxides are present in these fractions. In the fraction <0.001 mm in diameter separated from the ortsand interlayer the hydromica content is considerable; so too is the content of "readily mobile" iron compounds.

The distribution of the clay minerals down the soil profile indicates that there are no important differences of mineralogical composition between the clay fractions from the silty clay loam and those from the boulder sandy loam. It was established that the kaolinite content in the top part of the soil profile (3-8 cm) increases and that the montmorillonite increases in the B_1 horizon. The largest amount of "readily mobile gels" of iron and alumina was found in the illuvial horizon. Goethite is present in this horizon (Fig. 2).

As compared with the podzolic soils studied by Gorbunov (1) the strongly podzolic soil of the Zvenigorod Biological Station has a low content in hydromicaceous minerals and a considerable amount of kaolinitic mineral, with some accumulation of the latter in the top part of the soil profile.

We established a similar picture of the mineralogical composition of the colloidal clay fractions and its variation down the profile in the case of a coarse textured podzolic soil from the Karelian Isthmus (3). The accumulation of a kaolinitic mineral in the top part of soils has been described in the literature more than once (8-11). This effect seems to be fairly common in nature.

The following picture of the chemical and mineralogical composition of the clay fractions in a strongly podzolic soil emerges from the data discussed previously. The clay material is lost by the podzolic horizon, partly because its fine suspensions are removed and partly through subsequent weathering of the silicates contained in it. Clay minerals reveal different degrees of stability during podzol formation. Of the three minerals, hydromica, montmorillonite, and kaolinite, the last-named is the most stable. Consistently with the high migration capacity of potassium, magnesium, and iron, the hydromica content is lowest, despite the presence of huge reserves of primary minerals, many of which can be direct sources for the formation of this mineral. The distribution of the montmorillonite mineral down the soil profile indicates that it is less stable than kaolinite. This is probably due to its high degree of dispersion. We can also assume a connection between the low content of the A_2 horizon in this mineral and the intensive transport from the soil of elements of the first and second Polynov orders (4) and also of silica.

The order of relative mobility of the elements set out previously and the mineralogical composition of the clay fractions indicate that podzol formation makes for a relative accumulation of clay minerals with a low potassium and magnesium content, a narrower $SiO_2:Al_2O_3$ ratio, and a low exchange capacity. In the illuvial horizon the clay fraction is enriched with "readily mobile gels" of iron and alumina. The presence of goethite has been established. The montmorillonite content in this horizon is higher than in the podzolized horizon.

Conclusions

1. The clay material of a strongly podzolic soil is mobile. In the lower part of the A_2 horizon, and especially in the B horizon, it separates into optically orientated shells around particles of the primary minerals and of "coatings" at their wedges, and intrusions in the micropores and cracks in combination with organic matter and iron.

2. In the podzolic horizon the relative order of mobility of the elements is $K > Ca > Mg > Si > Al \approx Fe$. In this horizon all elements except the quartz silica which shows a relative accumulation, prove highly mobile.

3. The composition of the clay fractions includes clay minerals (montmorillonite and kaolinite with a slight admixture of hydro-

mica), amorphous iron, and alumina compounds, goethite and organic mineral compounds. The total chemical composition of clay is characterized by a low potassium and magnesium content and a $SiO_2:R_2O_3$ ratio of 2.5-2.7.

4. There is a relative accumulation of kaolinite in the top part of the podzolized horizon. An increased content in montmorillonite and in the amorphous R_2O_3 compounds was found in the illuvial horizon and goethite was detected. The clay matter of the ortsand interlayer shows a high hydromicaceous mineral content.

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SOME PHYSICAL AND CHEMICAL PROPERTIES OF DARK COMPACT MEADOW SOILS IN THE VOLGA-AKHTOBINSK BOTTOMLANDS

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In the Volga-Akhtobinsk bottomland, particularly its northwestern part, there are large areas of dark, compact, alluvial meadow clays. These peculiar bottomland soils have been studied little. Crop yields from them are often low.

Comparatively little has been written about these soils (2, 3, 4) interesting through they are both from the genetic and from the economic point of view. Compact alluvial soils generally form when there is temporary excess surface wetting in a central bottomland plain with small hummocks here and there, under asparagus-sedge-couch grass associations. During the low water period ground waters lie at a depth slightly below 2 m; their mineralization varies from 0.4 to 3 g/liter, and the type of salinization is usually sulfate-magnesium-calcium.

The soil profile is differentiated into well-defined genetic horizons. The humic horizons usually vary in thickness from 40 to 70 cm and are dark gray with a bluish tinge caused by the ferrous oxides formed when the soil profile is insufficiently aerated (gleization).

The morphological characteristics of these soils can be seen from a description of a profile in the northwestern part of the Volga-Akhtobinsk bottomlands, 900 m to the south of the southern boundary of the "III Reshayushchiy" farm. The gentle slope of plowland has a southwestern exposure. The ground water lies at a depth of 2.5 m.

A 0-26 cm. Dark gray, dry and compacted on top, damp, clayey, compact, porous-granular-blocky and vertically fissured below, with small roots. Transition distinct.

B 26-28 cm. Dark gray, with slight bluish tinge, wettish, clayey, very compact, vertically fissured, lumpy-nutty; structural units can be broken down only by mechanical action; has a sheen-like luster. Transition gradual.

CB 68-102 cm. Brownish-yellow with dark tongues of humus, damp, fine clay loams, compacted, blocky-nutty, occasional ocher patches of iron. Transition gradual.

C_1 102-125 cm. Grayish-yellow, damp, coarse clay loam, sandy loam in lower part, slightly compacted. Very occasional ocher patches of iron. Transition gradual.

C_2 125-175 cm. Brownish-yellow, fine sand with rare ocher patches. Transition gradual.

C_3 175-300 cm. Grayish-yellow, medium sand, wet.

As regards the texture of the top horizons these soils belong to the coarse and medium clays (Kachinskiy's classification). The values in Table 1 indicate that the top horizons, to a depth of 70 cm, contain more than 50% of the clay fraction. This high clay content, found in all compact soils, makes them tightly sealed and gives them unfavorable water-physical properties.

When the soil horizons are dry, compaction usually starts to become significant once there is a clay content of 30%-35% and it becomes intense when the clay content is over 50%. In giving prime importance to a high clay content in the formation of compact horizons, however, we must not ignore other accompanying factors which tend to increase compaction. We can assume that a high degree of compaction and deterioration of the water-physical properties of the humus horizon are due to attachment of the soil particles to poorly water-soluble chemical compounds, primarily $Fe(OH)_3$. "With excessive wetting, reduction processes develop in the soil, accompanied by the formation of water-soluble ferrous oxides, which impregnate the aggregates together with the soil solution" (1). On drying out, the ferrous oxide is converted into the ferric form.

The cementing process described by Kachinskiy (1) seems to be an extensive phenomenon in the formation of compact soils under the conditions of the Volga-Akhtobinsk bottomlands. Immediately after the spring rains, for example, one finds indications of excessive wetting, gleization, and marked stickiness in the profile of the compact soils. Towards autumn, when the flood-waters disappear and the ground waters are so reduced as to have no

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[1] The analyses were performed at the Southern Gypsum Trust laboratory.

Table 1

Particle-size analysis of dark compact meadow bottomland clay soils (%, Kachinskiy method)

Profile No.	Depth, cm	Losses on treatment with HCl	Particle diameter, mm						
			>0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	<0,01
47	0—26	4,12	1,36	5,32	12,08	9,12	13,20	59,92	81,24
	26—68	4,67	9,20	7,33	13,04	7,76	10,24	52,43	70,43
	68—102	3,05	23,70	21,65	9,20	4,00	7,20	34,25	45,45
	102—125	2,07	34,39	34,74	8,40	0.56	3,44	18,47	22.47
	125—175	0,84	32,22	58,54	2,96	0,40	1,44	4,44	6.28
	175—300	0,99	60,12	34,89	1,20	—	—	3,79	3,79
673	0—29	6,49	—	5,20	11,81	6,05	24,18	52,76	82,99
	29—48	8,65	—	9,05	12,06	5,80	17,13	55,96	78,89
	48—82	9,21	0,16	12,35	18,37	5,09	11,91	52,12	69,12
	82—118	3,67	—	38,89	22,00	7,28	2,24	29,59	39,11
	118—185	1,12	0,26	79,66	7,20	0,96	2,16	9,76	12,88
	185—280	0,72	0,47	86,81	4,48	4,16	1,36	2,72	8,24

Note: Comma represents decimal point.

influence on the wetting of the surface soil, considerable changes occur in the soil profile. The high summer air temperatures, combined with low rainfall (mean July-August temperature is +24-25°C, precipitation 23-26 mm) make for rapid drying of the soil surfaces. This in turn causes intensive cracking. The ferrous oxide is partially converted into ferric oxide; in the presence of high clay content the soil becomes strongly compacted.

The slightly lower degree of compaction and better water-physical properties of the topmost layer, despite the presence of a larger amount of clay fraction in some cases, in our opinion is due to the meliorative action of the plant root system and the biochemical activity of the microflora (Table 2).

The humus content of the plow layer usually varies from 3%-5%, decreasing to 2%-2.5% in the B horizon.

The distribution of nutrients down the profile follows a similar pattern. The plow layer contains 6-12 mg of available phosphorus and 5-9 mg of potassium per 100 g of soil, and 0.17%-0.23% total nitrogen. In the B horizon the available phosphorous content is less than 6 mg per 100 g of soil, the potassium content less than 5 mg, and the total nitrogen 0.11%-0.16%.

The poor supply of available forms of potassium and phosphorus in compact soils indicates a need for organic and mineral fertilizers.

The higher humus and nutrient content in the top horizon as compared with the lower horizons is due to the poorer penetration of the plant root system and sharp deterioration of the water-physical properties of the subjacent horizons, accompanied by greater suppression of microbiological activity.

As Table 3 shows, the "compact" B horizon which has the highest bulk density (1.60 g/cm³) and the lowest porosity (40%), possesses particularly unfavorable water-physical properties. Specific gravity increases from 2.4 in the A horizon to 2.71 in the C horizon. Maximum hygroscopicity and maximum field moisture capacity diminish with depth: the former from 13.0% to 6.1%, the latter from 39.0% to 18.0%. This is due to the decrease in humus content and coarser texture with depth. As regards content in soluble salts, one finds both practically non-salinized soils in which the dry residue does not amount to 0.1% (profile 47), and salinized soils with a dry residue of more than 0.8% (Table 4).

Salinization is usually of the sulfate type. In all profiles the predominant anion is the $SO_4^=$, which, in the horizons where salt accumulation is intensive, amounts to 10-12 meq/100 g of soil. The HCO_3^- content is lower and the Cl^- lower still.

Of the cations, Ca^{++} occurs in greatest quantities (up to 7 meq in the salt-accumulating horizons) Mg^{++} and Na^+ in smaller amounts, the prevalence of one over the other often varying from one horizon to another.

If we trace the variation in cation and anion content along the soil profile we find the following pattern emerges: from the ground waters upward the content of water-soluble salts gradually increases, to reach a peak at a specified depth (48-82 cm in the case of profile 673, 30-67 cm in profile 628), and

Table 2

Chemical analysis of compact soils

Profile No.	Horizon and depth, cm	Humus (Tyurin method), %	N (Kjeldahl method), %	Available		CO_2, %	$CaCO_3$, %
				P_2O_5 (Arrenius meth.)	Potassium (Peyve method)		
				Mg per 100 g			
666	A 0—25	4,26	0,212	9,0	5,2	0,15	0,34
	BC 25—42	1,96	0,102	6,0	None	0,12	0,27
	B 42--52	1,45	—	—	—	1,40	3,18
673	A 0—29	4,42	0,222	6,0	8,6	0,10	0,23
	B 29—48	2,23	0,111	5,0	5,2	0,19	0,43
	BC 48—82	1,75	0,106	—	—	—	—
628	A 0—23	3,51	0,173	Not det'd.		0,12	0,27
	B 23--42	3,16	0,161	"		0,13	0,30
47	A 0—26	4,57	0,229	12,0	6,5	0,12	0,27
	B 26—68	2,16	0,110	6,0	None	0,13	0,30
	BC 68—102	1,35	—	—	—	0,10	0,23

Note: Comma represents decimal point.

Table 3

Water-physical properties of dark compact coarse clay meadow bottomland soil

Genetic horizons	Depth, cm	Bulk density, g/cm³	Specific gravity	Porosity, %	Maximum hygroscopicity, %	Maximum field moist. capacity, %
A	0—19	1,44	2,64	45	13,0	39,0
B	19—70	1,60	2,67	40	11,9	26,6
C	82—190	1,52	2,71	43	6,1	18,0

Note: Comma represents decimal point.

Table 4

Analysis of water extracts of dark compact meadow bottomland clay soils

Profile No.	Depth, cm	In meq per 100 g of soil								
		Dry residue, %	Ca^{++}	Mg^{++}	$Na^+ + K^+$ by differ.	Cl^-	$SO_4^=$	HCO_4^-	Total, meq.	$\frac{Cl^-}{SO_4^=}$
47	0—26	0,0600	0,634	0,181	0,202	0,155	0,462	0,400	2,034	0,33
	26—68	0,0800	0,739	0,214	0,287	0,155	0,685	0,400	2,480	0,22
	68—102	0,0860	0,634	0.181	0,471	0,116	0,770	0,400	2,572	0,15
	102—125	0,0700	0,524	0.214	0,363	0,116	0,685	0,300	2,202	0,17
673	0—29	0,0620	0,314	0,255	0,487	0,251	0,223	0,582	2,112	1,12
	29—48	0,3600	2,725	1,258	1,431	0,155	4,797	0,462	10,828	0,03
	48—82	0,8380	6,658	2.944	2,704	0,116	1,788	0,402	24.712	0,01
	82—118	0,1960	0,998	0,469	1,442	0,271	2,176	0,462	5,818	0,12
	118—185	0,1180	0,893	0,362	0,594	0,212	1.235	0,402	3,698	0,18
	185—280	0.0300	0,160	0,214	0,184	0,135	1,102	0,321	1,116	0,12

Note: Comma represents decimal point.

decreases again towards the surface.

The precipitation of salts from solution occurs as a function of their solubility and of the moisture content in the soil at the point where the soil and ground waters, rising by capillarity, reach the dry horizons of the soil and evaporate.

The carbonates ($CaCO_3$, $MgCO_3$) are precipitated first and the sulfates ($CaSO_4$, $MgSO_4$ and a certain amount of Na_2SO_4) slightly later, but the soil solution does not yet reach the saturation limit in regard to monovalent metal sulfates and is concentrated slightly above the calcium and magnesium sulfate maximum, while the (Ca^{++} + Mg^{++}): Na^+ ratio diminishes.

Analysis of the water extracts shows that the greater accumulation of monovalent Na^+ as compared with Ca^{++} and Mg^{++} occurs in the topmost horizons (profiles 89, 673, 628) where there is naturally also a greater possibility for the Na^+ to penetrate the adsorption complex of the soil.

A further interesting point is that in the surface horizons of salinized compact soils in embanked bottomlands, the accumulation of monovalent sodium sulfates is more pronounced than in similar soils in areas which are not embanked. This can be traced by comparing profile 628, which is situated in a non-embanked area, with profile 89, where the land is banked up (see Fig. 1). As regards water-soluble salt content, both profiles should be classified as medium-salinized (maximum salt content in profile 628 is 0.710%, in profile 89, 0.592%).

In the B horizon, profile 628 contains 7.22 meq Ca^{++}, 2.294 meq Mg^{++}, and 1.173 meq Na^+. The corresponding values for the B horizon in profile 89 are 0.893 meq Ca^{++}, 0.896 meq Mg^{++}, and 6.829 meq Na^+.

The accumulation of monovalent sodium sulfates in the salinized soils of the embanked area is due to the absence of leaching by flood waters, which often makes for an appreciable lowering of productivity in embanked soils. The data for the water extracts, cited previously, show that salinization of embanked areas, to judge from the quantity of dry residue, is similar but that the quantitative ratios between the salts often vary greatly.

Analyzing the values shown in Table 5 one readily sees that the sum of adsorbed Mg^{++} and Ca^{++} in the top horizons reaches high values and varies from 49.89 meq to 56.05 meq/100 g of soil. The increased content in adsorbed Mg^{++} is noteworthy, the amount of this element in the surface horizons of compact soils varying from 10.4 to 24 meq/100 g of soil, or 22% in the first case and 96% in the second case of the adsorbed Ca^{++}.

The amount of adsorbed Na^+ (2.6%-5.5% of adsorption capacity) makes it impossible to speak of clear solonetzization of these soils, but it should be assumed that when the clay fraction in the surface horizons is large (more than 42%-45%) the presence even of small amounts of adsorbed Na^+ must in some measure make for deterioration of the soil's agriculturally useful physical properties.

Conclusions

1. Dark meadow bottomland and compact clay soils are common in the Volga-Akhtobinsk bottomland, especially in its northwestern part; these soils form under conditions of

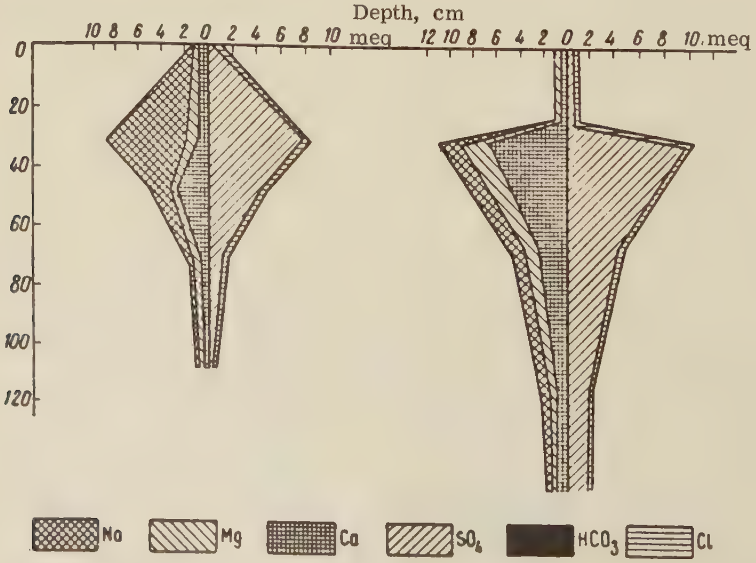

Fig. 1. - Salinized soil profiles: A - in embanked area, profile 89; B - in non-embanked area, profile 628.

Table 5

Composition of adsorbed bases in dark compact meadow bottomland clay soils

Profile No.	Depth, cm	Ca^{++}	Mg^{++}	Total $Ca^{++}+Mg^{++}$	Na^{+}	Ca^{++}	Mg^{++}	Na^{+}	Ratio $\frac{Mg^{++}}{Ca^{++}}$
		Meq				In % of capacity			
47	0—26	45,388	10,667	56,055	3,270	76,5	18,0	5,5	0,23
	26—68	40,611	10,469	52,080	2,139	76,3	19,7	4,0	0,22
	68—102	27,346	6,925	34,271	1,061	77,4	19,6	3,0	0,21
666	0—25	28,923	23,685	52,608	Not det'd.				0.82
	25—42	25,374	24,516	49,890	—	—	—	—	0,96
628	0—23	41,011	12,352	53,363	2,139	73,9	22,3	3,8	0,30
	23—30	40,612	14,499	55,111	1,496	71,8	25,6	2,6	0,35

Note: Comma represents decimal point.

temporary excess surface wetting in an enclosed level bottomland.

2. The amount of humus, total nitrogen, and available phosphorus decreases with depth down the profile in these soils, owing to the deterioration of their water-physical properties, the weak penetration of the plant roots, and the suppression of microbiological activity in the B horizon.

3. The heavy compaction of the soil profile is due, in varying degrees, to the high clay content (>40%-45%) and also the cementing of soil particles by iron hydroxide and the presence of monovalent sodium in the soil adsorption complex.

4. Compact soils possess unfavorable water-physical and agricultural properties, and therefore cannot give high, stable crop yields in their present form.

The somewhat better properties of the surface layer of these soils is due to the meliorating effects of the plant roots and the biochemical activity of soil microflora.

5. Comparing the salinized varieties of compact soils formed under embankment conditions with those found in a non-embanked bottomland, we see that sodium sulfate accumulation in the soil profile is more intensive in the embanked parts.

6. When compact soils are brought under cultivation, the following measures are necessary in order to improve their qualities: application of organic and mineral fertilizers, adding sand, gradual deepening of the plow layer, with successive and as frequent as possible cultivations (disking and harrowing) to improve the aeration of the surface horizons, and the sowing of perennial grasses.

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SOIL-FORMING PROCESSES IN THE CENTRAL PART OF THE AMUR-ZEIA INTERFLUVE

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The soils of the Amur-Zeia interfluve were hardly studied at all until recently. Detailed investigation of the region's soil was started by the Main Resettlement Board and the Amur expedition in 1908-1912. Summarizing the research material at that time, Glinka (3) wrote: "The soils of the Amur region belong almost exclusively to two groups, podzolic and bog." By 1937, however, Liverovskiy (6) turned his attention to the peculiarity of the weathering and soil-forming processes in the Upper Zeia region. In particular he noted that the soils had features similar to those of regions with a warm temperate and humid climate.

In recent years, mainly as a result of work done by joint expeditions of the Council for the Study of Productive Resources and Soil Institute of the Soviet Academy of Sciences in 1953-1959, the Amur soils became the subject of all-round and thorough study for the first time. New data made it imperative to review existing opinions about the nature of the weathering and soil-forming processes. On the basis of these investigations we must regard the group of brown forest soils (8) as the zonal group of Cis-Amur and Primor'ye forest soils, although some soil scientists still adhere to the former idea that sod-podzolic soils are the zonal type of forest soils here (12).

During the field seasons of 1957-1959, a joint soil-melioration detachment of the Council for the Study of Productive Resources forming part of the Amur expedition worked under the direction of V. A. Kovda in the center of the Shimanovskiy district of the Amur province, with the aim of obtaining a more detailed description of soil formation in the Cis-Amur region. The soil-forming processes were studied in the central part of the Amur-Zeia interfluve. This central part belongs to a coniferous-broadleaf subzone, transitional between the south taiga and the broadleaf forest zone.

As regards area, forests predominate here. Pine-birch-larch forests with underbrush of hazel and Dahurian rhododendron are widespread in the divides and on the slopes, where clay and clay loam lying, near the surface, on sand are the soil-forming parent material. The grass cover in such forests is somewhat sparse and consists of various grasses. In the level watersheds and on the gentle slopes, where thick layers of sand are the soil-forming parent material, there are extensive birch and larch-birch forests. In such forests there is usually a very generous grass cover of sedge and beach grass.

The soil study was based on selected permanent plots, each consisting of about 150 ha, which were made the subject of soil surveys (scale 1:10,000). One of the permanent plots "Krasnaya Zarya," consisted of a northern exposure slope, running 2-3° from the watershed to the bog bottomland of the Vtoroy Ivtugan River. Here the soils are mainly brown forest podzolized, under pine-birch-larch. A second plot, "Belovezh," consists of a southwestern exposure slope, running 1-2° from the watershed to the bog bottomland of the Urga River. Here, brown forest gley podzolized soils form under a thinned birch forest. The profiles of the soils studied are described below.

Profile 82, Krasnaya Zarya. Mixed pine-birch-larch with hazel and Dahurian rhododendron underbrush. The grass cover consists of a mixture of lespedeza, lily of the valley, shinleaf, stoneberry, broadleaf ladybell and other grasses, providing a 50%-60% cover. The soil is brown forest podzolized.

A_0 0-1(2) cm. Strongly carbonized dry undergrowth of needles, leaves, grass and twigs.

A_SA_1 2-10 cm. Moistened, dark gray, strongly penetrated by plant roots, poorly mineralized, loose. Transition clear.

A_2 11-24 cm. Moistened, light gray to straw-colored, with brownish tinge; coarse clay loam, stratified, unstable blocky-porous structure; loose, many tree and grass roots. Transition clear.

B_1 25-44 cm. Moistened, brown fine clay loam; compacted, loose-blocky structure, plant and grass roots. Transition gradual.

B_2 45-66 cm. Moist, straw-colored and brown, fine clay loam; unstable nutty structure, compacted, some lenses of sand, few roots. Transition with tongues, gradual.

BC 67-86 cm. Moist, dark-straw colored-brown, with gray and rusty patches of iron and dark spots of manganese; fine clay loam; compacted, small nutty, porous, isolated roots. Transition gradual in the forms of tongues and pockets.

C 87-143 cm. Damp, unevenly colored with rusty and blue patches of iron and dark intercalations of lacustrine humus; fine clay loam; lumpy-nutty structure, ortstein, powdering of SiO_2 on faces of structural units. Transition uneven, abrupt.

D below 144 cm. Damp, straw colored-rusty with bluish intercalations, medium granular sand.

These soils present good natural drainage, since at a depth of 10-150 cm they are underlaid with sand.

Profile 41, Belovezh. Thinned birch forest. Grass cover a mixture of beach grass, burnet, false hellebore, cinquefoil, sedge and others, providing an almost 100% cover. Soil, brown forest gley podzolized.

A_0 0-1 cm. Moist, carbonized litter of leaves and grass.

A_0A_1 2-5 cm. Moist, dark cinnamon-brown, heavily sodded, fairly compact. Transition gradual.

A_1A_2 6-12 cm. Moist, grayish brown fine clay loam, small blocky-granual structure, compacted, penetrated by grass roots; fine ortstein grains occur. Transition gradual, conspicuous.

A_2B_1 13-22 cm. Damp, light brown, clayey, blocky-porous structure, compacted; many roots; fine grains of ortstein occur; slight gleization traceable. Transition gradual.

B_1 23-41 cm. Wet, water trickles from walls of profile, dark brown, clayey, compacted, blocky-granular structure; ortsteins, quartz particles on faces of structural units, small rusty and bluish patches of ferrous and ferric iron, a good many tree and plant roots. Transition gradual.

B_2(g) 42-66 cm. Wet, dark brown, gleyed in patches, clayey, compacted, blocky-granular structure. Ortsteins, few roots. Transition gradual, conspicuous.

BC(g) 67-87 cm. Wet, dark brown, with bluish and rusty patches of iron, clayey, compacted, blocky-nutty structure, isolated roots. Transition gradual.

C(g) 87-130 cm. Damp, varicolored with rusty and bluish intercalations of iron and black patches of manganese, clayey, not pronounced prismatic structure, compact, powdering of SiO_2 on faces of structural separates.

A thick layer of sand underlies the clay in these soils at a depth of about 6 m.[1] The

Table 1

Some chemical and particle-size analysis data

Profile No.	Horizon	Depth, cm	Humus (Knopp's method, %)	pH		Adsorbed cations, meq						Unsaturation, %	% of particles	
				Water	Salt	Ca^{++}	Mg^{++}	Na^{+}	H^{+}	Al^{++}	Total		<0,01 mm	<0,001 mm
82	A_SA_1	0—10	3,89	6,87	6,56	16,88	1,88	1,06		0,06	19,88	0,3	25,4	9,6
	A_2	12—22	0,31	6,49	5,73	4,83	0,32	0,04	0,01	0,02	5,22	0,6	23,7	10,5
	B_1	28—38	0,24	5,61	4,47	11,09	1,94	—	0,01	0,76	13,80	5,6	44,4	29,0
	B_2	48—58	0,22	5,52	4,37	13,38	2,80	0,10	0,01	0,76	17,05	4,5	48,0	33,2
	BC	75—85	0,25	5,73	4,40	13,81	3,92	—	0,02	0,37	18,13	2,2	54,9	35,9
	C	109—117	—	5,64	4,68	8,38	7,00	—	0,01	0,25	15,64	1,7	49,6	29,4
41	A_sA_1	0—5	11,68	7 09	6,30	26,78	10,66	—	0,06	0,22	37,72	0,7	46,7	16,5
	A_1A_2	6—11	2,18	5,54	4,28	12.71	3,41	—	0,03	0,34	16,49	2,2	68,1	37,5
	A_2B_1	12—22	0,71	5,39	4,20	15,39	2,80	1,14	0,01	1,64	21,18	7,7	72,1	42,3
	B_1	30—40	0,69	5,25	4,11	16,35	4,17	—	0,01	3,04	23,57	12,9	75,9	47,0
	BC_g	70—80	0,35	5,30	4,11	17,60	7,24	—	0,02	1,72	26,58	6,5	75,5	48,2
	C_g	120—130	—	5,63	4,40	17,16	7,80	—	0,01	0,69	25,66	2,7	75,8	51,6

Note: Comma represents decimal point.

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[1] From data on borings (cited by N.D. Pustovoytov).

Table 2

Total chemical analysis

Profile No.	Horizon	Depth, cm	Hygroscopic water, %	Ignition loss %	SiO_2	R_2O_3	Fe_2O_3	Al_2O_3	TiO_2	P_2O_5	CaO	MgO	MnO	Na_2O	K_2O	SO_3	Molecular ratios			
					In % of ignited soil												$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Fe_2O_3}$	$\frac{SiO_2}{R_2O_3}$	$\frac{Al_2O_3}{Fe_2O_3}$
82	A_SA_1	0—10	1,56	7,80	75,53	17,23	1,99	14,70	0,44	0,10	1,62	1,11	0,13	2,19	2,85	0,81	8,74	101,6	8,08	11,6
	A_2	12—22	0,49	1,92	75,96	15,32	1,49	13,38	0,41	0,04	1,37	0,95	0,02	2,64	3,45	0,60	9,69	136,2	8,88	14,0
	B_1	28—38	2,26	3,55	72,63	19,13	3,91	14,73	0,45	0,04	1,28	1,14	0,01	2,23	3,19	0,19	8,40	49,6	7,18	5,91
	B_2	48—58	2,32	4,32	71,10	19,81	4,27	15,09	0,43	0,05	1,19	1,06	0,01	2,47	3,40	0,27	7,92	45,2	6,76	5,55
	BC	75—85	2,66	3,90	68,60	23,88	5,17	18,15	0,53	0,03	1,11	1,23	0,04	1,90	2,74	0,32	6,40	35,3	5,47	5,51
	C	109—117	2,44	3,16	70,01	22,61	4,73	17,34	0,53	0,04	1,16	1,17	0,04	2,81	3,22	0,38	6,82	39,4	5,82	5,77
		280—300	0,45	0,90	76,79	14,49	0,98	13,30	0,18	0,03	1,49	0,46	0,01	1,81	3,52		9,85	208,8	9,39	21,2
41	A_SA_1	0—5	6,60	37,66	64,65	25,46	7,57	15,94	1,23	0,72	3,72	2,50	0,70	1,30	2,20	0,61	6,89	22,7	5,28	3,27
	A_1A_2	6—11	2,77	8,44	69,02	25,02	6,68	17,38	0,88	0,08	1,06	1,56	0,23	1,65	2,76	0,56	6,75	27,6	5,42	4,08
	A_2B_1	12—22	3,65	9,12	66,15	28,44	7,34	20,13	0,94	0,03	1,11	1,59	0,14	1,21	2,48	0,60	5,59	24,1	4,54	4,30
	B_1	30—40	4,26	9,77	65,00	29,99	8,62	20,40	1,01	0,06	1,05	1,90	0,14	1,02	1,60	0,68	5,42	20,2	4,27	3,72
	BC_g	70—80	4,31	9,75	64,72	29,77	7,84	20,83	1,00	0,10	1,12	1,61	0,14	1,20	2,37	0,26	5,27	22,1	4,26	4,18
	C_g	120—130	4,17	9,18	64,87	28,57	8,10	19,43	0,95	0,9	0,95	1,79	0,14	1,21	2,28	0,48	5,68	21,4	4,49	3,77
		230—250	4,20	5,32	64,97	26,69	6,37	19,34	0,79	0,19	1,30	1,85	0,09	1,59	2,86	0,31	5,72	27,2	4,73	4,76

Note: Comma represents decimal point.

natural drainage of these soils is very poor.

The distribution of physical and colloidal clay particles shows that the top part of the soil profile is poor in these (Table 1). This impoverishment, starting from the top horizon and continuing as far as the soil-forming parent material, appeared most acute in profile 82. In profile 41 a less abrupt change of particle-size distribution within the soil profile is to be noted.

The pH of the water suspension in these soils varies from slightly acid to neutral (5.3-7.1), being higher in the top horizons. The soils studied were saturated with cations. Extreme unsaturation (6%-13%) appeared only in the B horizon.

The total analysis data (Table 2) indicate a distinct removal of alumina and a slight removal of magnesium from the top soil horizons and an accumulation of these in the illuvial horizons. No calcium, sodium, potassium, or manganese loss was detected. The leached horizons can be distinguished by the high silica content. In the well-drained soil of profile 82, the iron is removed and accumulates in the illuvial horizons. In profile 41 it is distributed fairly evenly along the profile and there is negligible accumulation in the illuvial horizons.[2] We shall explain below the reason for the varying distribution of total iron in the profile.

The soil solutions were studied during the summer field season of 1957-1959, except in the case of profile 82, where the soil solutions were studied only from 1958 onwards. The solutions were separated by means of an oil press in an instrument designed by Kryukov. Naturally moistened samples were used for this purpose, immediately after being collected from the field. The solution was separated at a pressure of 50-100 kg/cm².

The HCO_3^-, Cl^-, $SiO_3^=$, Ca^{++}, Mg^{++}, Fe^{++}, Fe^{+++} content in the solutions and the pH were determined in the course of three field seasons; the soluble organic matter $SO_4^=$ and NH_4^+ were determined from 1958 onwards; the various forms of titratable acidity were determined only in 1959. Attempts to determine the phosphorus and aluminum in the soil solutions and in the waters were unsuccessful and these elements were not detected in a single instance. The analyses of the soil solutions were performed under field conditions.

The samples for soil solution separation were collected at three periods of the year; first, in early summer before the monsoon rains, secondly, in midsummer during the monsoon rains, and thirdly, in the fall after the monsoon rains.

We shall now examine the most typical features of the soil solutions studied. The solutions obtained from the topmost organogenic horizon were slightly turbid, owing to the admixture of colloidal and clay particles. After standing the solutions provided almost colorless or had a slight greenish-yellow color. The solutions from the lower horizons were more turbid and after standing were colorless.

A peculiarity in chemical composition of the soil solutions studied was the low content in water-soluble organic matter (Table 3). The solutions from the top organogenic horizons contained the largest amounts of water-soluble organic matter. In profile 82, for example, the organic content reaches a peak of 300 mg/liter; in profile 41 the corresponding figure was 90 mg/liter. The eluvial horizons contained far less organic matter and the lower horizons still less.

The titrable acid of the solutions was due mainly to the presence of carbon dioxide, which made up 90% of the total titrable acid in the humus-accumulative horizons. Acidity caused by free non-volatile organic acids is not significant. The pH varied only from slightly acid to slightly alkaline (6.1-7.6).

The soil solutions contained very little iron in trivalent form. Only in the humus-accumulative horizons did the iron concentration reach 0.3-0.5 meq/liter; lower down the profile the iron concentration decreased sharply. Trivalent iron was often completely lacking from the solutions. The bivalent iron from the humus-accumulative horizons differed little from the concentration of ferric oxide, but ferrous oxide was always a good deal more plentiful than ferric in the solutions from the lower horizons.

Among the anions in the humus-accumulative horizons, bicarbonates predominate. Lower down the bicarbonate concentration decreases and other anions gradually become predominant.

The distribution of calcium concentrations follows a similar course to that of the bicarbonates, but the absolute calcium values are higher. When the dry residues from the soil solutions were examined under the microscope it was found that the calcium was bonded mainly with $SO_4^=$ and HCO_3^- and that very small amounts were bonded also with chloride.[3] The magnesium distribution was similar to that of calcium but the content in the solutions was smaller.

The silica content in the solutions was high by comparison with soil solutions from the forest belt of the European part of the USSR. Unlike the other components of the solution, silica was invariably concentrated mainly in the lower horizons.

In addition to studying the chemical composition of the soil solutions, we also performed regular selections and analyses of test samples of subsoil, ground water, and river water. Some of the chemical analysis results are shown in Table 4.

The active reaction of the subsoil waters

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[2] In soils of this sub-group, according to the values for other profiles, the distribution of total iron along the profile is generally uniform.

[3] The microscopic examination was performed by I.I. Feofarova.

Table 3

Limits of variability in composition of soil solutions

Profile No.	Depth, cm	pH	Acidity in meq. H+ per liter		Soluble organic matter, mg/liter	HCO_3^-	Cl^-	$SO_4^=$
			Total	From CO_2		meq		
82	0—10 12—22 28—38 48—58 75—85 109—117	6,4—7,2 (5,9)[a] 6,1—7,1 6,3—7,3 6,2—7,0 6,4—7,2 6,3—7,6	1,8—2,2 0,4—0,6 0,2—0,3 0,2—0,3 0,1—0,4 0,1—0,3	1,6—2,0 0,2—0,4 0,2—0,2 0,1—0,2 0,1—0,3 0,1—0,3	44,0—301,6 10,8— 54,7 11,0— 42,4 5,2— 18,1 7,8— 18,6 5,4— 31.0	0,9—3,4 (0,5) 0,1—0,5 0,1—0,4 0,2—0,3 0,1—0,4 0,1—0,6	0,0—0,8 0,1—0,4 (1,2) 0,0—0,4 0,1—0,5 0,0—0,3 0,0—0,8	0,2—0,5 (1,8) 0,1—0,5 0,1—0,7 0,3—0,8 (0,0) 0,0—0,5 (1,2) 0,2—0,9
41	0—5 6—11 12—22 30—40 70—80 120—130	6,5—7,5 (5,7) 6,4—7,3 6,2—7,1 6,4—7,3 (5,9) 6,1—7,0 (5,7) 6,0—7,1	1,7—2,6 0,1—0,5 0,2—0,6 0,2—0,2 0,1—0,2 0,1—0,1	1,4—2,5 0,1—0,4 0,1—0,4 0,1—0,2 0,1—0,1 0,1—0,1	15,6—88,4 0,0—46,5 2,7—25,9 0,0—20,7 0,0—25,9 5,2—31,0	1,0—2,5 (0,6) 0,2—0,6 0,2—0,6 0,1—0,3 (0,5) 0,1—0,4 0,1—0,4 (0,7)	0,2—0,9 0,1—0,7 (1,1) 0,1—0,7 (1,0) 0,0—0,5 0,3—1,0 0,1—0,7 (2,7)	0,1—1,8 0,0—0,6 0,1—0,9 0,1—0,5 0,2—0,6 0,3—1,7

Profile No.	Depth, cm	$SiO_3^=$	Ca^{++}	Mg^{++}	NH_4^+	Fe^{++}	Fe^{+++}
		meq					
82	0—10 12—22 28—38 58—58 75—85 109—117	0,5—0,7 0,4—0,6 0,4—0,6 0,5—0,6 0,4—0,8 0,5—0,8	0,6—1,6 (4,5) 0,3—0,6 0,3—0,7 0,3—0,6 0,2—0,7 0,3—0,7	0,5—1,0 (3,3) 0,1—0,4 0,2—0,4 0,1—0,4 0,1—0,4 (0,6) 0,2—0,5	0,1—0,5 (0,9) 0,1—0,5 0,1—0,4 0,1—0,4 0,2—0,4 0,1—0,5	0,02—0,1 (1,4) 0,02—0,1 (1,1) 0,02—0,1 (0,5) 0,02—0,4 0,02—0,1 (0,4) 0,01—0,1 (0,8)	0,04—0,4 0,03—0,1 0,01—0,1 0,01—0,1 0,00—0,1 0,00—0,1
41	0—5 6—11 12—22 30—40 70—80 120—130	0,5—0,8 0,5—1,0 0,5—0,8 0,6—0,9 0,6—1,4 (2,4) 0,7—1,6 (2,8)	0,6—2,3 0,3—0,8 0,2—0,8 0,2—0,5 0,2—0,8 0,3—1,2	0,3—1,5 0,1—0,6 0,1—0,5 0,1—0,4 0,1—0.5 0,2—0,8	0,0—0,6 0,0—0,2 0,1—0,3 0,1—0,4 0,1—0,3 0,1—0,4	0,03—0,6 0,01—0,2 0,00—0,3 0,00—0,2 0,01—0,3 0,00—0,2	0,03—0,4 0,01—0,1 0,01—0,1 0,00—0,1 0,00—0,07 0,00—0,2

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[a] The values in parentheses indicate isolated highest and lowest concentration values.

Note: Comma represents decimal point.

was as a rule weakly acid, but occasionally reached weakly alkaline values. The pH of the river and subsoil waters rarely fell below neutral.

An almost invariable feature of all the types of water studied was the prevalence of silica, an indication that this substance was mobile. Water-soluble organic matter

Table 4

Chemical composition of waters, 1959

Date	Source	Depth, m	pH	Soluble organic matter, mg/liter	HCO_3^-	Cl^-	$SO_4^=$	SiO_3^-	Ca^{++}	Mg^{++}	NH_4	Na^+	K^+	Fe^{++}	Fe^{+++}
					Meq/liter										
July 22	Profile 41	0,5	6,64	1,6	0,30	0,26	None	1,10	0,18	0,12	0,17	0,30	0,15	None	
Sept.14	Profile 44	0,8	6.50	Trace	0,80	0,73	0,14	0,63	0,44	0,35	0,10	Not det'd.		0,06	None
July 10	Belovezh boring	22	7,16	"	1,43	0,26	None	1,44	0,53	0,51	0,14	"		None	
June 24	Urga River	—	7,33	None	0,55	0,15	"	1,33	0,25	0.15	0,12	0,40	0,22	None	Trace
July 27	Pervyy Ivtugan River, "Krasnaya Zarye"	—	7,18	Trace	0,22	0,15	"	0,66	0,11	0,10	Trace	0,18	0,13	"	0,01

Note: Comma represents decimal point.

was practically absent from the waters; iron was either lacking or occurred in negligible concentrations.

We shall now compare some of our analytical findings with data relating to soils in which podzolization processes occur.

The first stage of podzolization is, of course, the appearance of exchangeable acidity (Gedroyt's method), the hydrogen content in the top horizons sometimes exceeding 90% of the total adsorbed cations (9, 10). This is the result of the formation of acid products from the decomposition of litter.

In the soils studied the absolute values for pH, adsorbed aluminium, and hydrogen and their distribution along the profile differ from those found in podzolic soils. Unsaturation of the top horizons was practically zero.

The appearance of a hydrogen ion, not only in exchangeable form but also as a component of the soil solution, is a characteristic feature of podzol formation processes. Our investigations showed that in the soil solutions studied there were hardly any strong non-volatile organic acids. This is borne out by the absolute pH values of the soil solutions. Rode's investigations (10) showed that in solutions where the pH was above 6.3 non-volatile organic acids occurred, if at all, in negligible amounts.

A further important determining feature of soils of the podzolic group is a high concentration of water-soluble organic matter. Organic matter is the main component of the solution and its concentration in the organogenic horizons amounts to 0.8 g/liter (2, 13, 14, 15). In the solutions from the humus-accumulative horizon it always greatly predominates over the mineral residue in weight; nor does its quantity usually fall below that of the mineral residue in the solutions from the lower mineral horizons. On the other hand, soil solutions from the soils under study were extremely poor in water-soluble organic matter, which was invariably conspicuously below the mineral residue in weight. This is probably due to the quite different group and fraction composition of the humus (Table 5).

The analysis data for the group and fraction composition of the humus indicate a marked predominance of humic over fulvic acids. The total fulvic acid content is very low. Among the humic acids the sesquioxide fraction (free and bonded with free forms) predominates. The fractions of humic and fulvic acids firmly bonded with calcium greatly predominate over the fractions firmly bonded with sesquioxides. The hydrothermal conditions are apparently sufficiently favorable for the formation and fixation of humic substances in the top organogenic horizons of forest soils, despite the temporary excess wetting during the monsoon rains. In addition, the sources of humus formation — grasses and leaf-fall — make for the fixation of humic substances. Lastly, the physical and chemical properties of the soils must also foster humus fixation, since the exchange capacity of these soils is fairly high, the adsorption complex is saturated with cations, and humification is occurring under the conditions provided by a neutral medium.

The major events in the processes of podzol formation are the removal of aluminum, iron, and other decomposition products from the top horizons. We mentioned previously that aluminum was never once found in appreciable quantities in these soil solutions. The most probable form in which aluminum migrates in the soil profile is that of its complex compounds with organic acid anions. The bicarbonates present in the solution, however, must act as a major obstacle to the formation of complex aluminum compounds with organic acids. We should take it that, with a pH above 5.7-5.9,

Table 5

Group and fraction composition of forest soil humus, percentage of total carbon (Kononova's method).

Profile No.	Depth, cm	Initial organic matter	Wax resins	Decalcinate	Humic acids				Fulvic acids			Non-hydrolyzable residue	Total	Humic acid carbon / Fulvic acid carbon
					Fractions			Total	Fractions		Total			
					Ia	I	II		I	II				
82	0—10	3,5	6,1	14,4	14,3	4,0	2,1	20,3	11,7	1,3	13,0	36,9	100,7	1,6
41	0—5	12,7	6,5	9,7	20,4	5,8	0,7	26,9	15,9	0,4	15,6	39,4	98.1	1,7
41	6—11	0,93	5,3	11,8	22,6	5,9	None	28,5	13,1	3,5	16,9	32,3	94,7	1,7

Note: Comma represents decimal point.

there will always be bicarbonates in the soil solutions, preventing the conversion of aluminum into a mobile form (10).

Considering this, we can say that conditions either for the decomposition of the aluminosilicate colloidal complex or for the loss of aluminum in the form of complex ions with organic acids do not seem to exist at present in the soils studied.[4]

Ferric oxide, like alumina, is present in the soil solution in the form of complex compounds with organic acid anions. As we mentioned previously, the solutions of the soils investigated were extremely poor in water-soluble organic matter, possibly because of the low concentrations of ferric oxide in the solutions as compared with solutions from podzolic and sod-podzolic soils. Ferric oxide migration in the soil profile is in fact hardly detectable. The iron migrates only in ferrous form.

To explain the difference distribution of total iron in the profile of the soils studied we shall examine the values for the seasonal variation on ferrous iron and chloride in the soil solutions and the chloride variation in water extracts from profiles 82 and 41 for the year 1959 (Table 6). We see that the peak concentrations of ferrous iron and chloride in the soil solutions and the chloride in the water extracts in the top horizons of profile 82 occur only during the first period (before the monsoon rains). From the second period onwards (during the monsoon rains) there was intensive leaching of chloride and ferrous oxide and maximum concentrations of these were detected in the lower horizons. In profile 41 there was also intensive leaching of chloride and ferrous oxide from the top horizons during the monsoon rains but in the third period, after the monsoon rains, maximum concentrations of these elements were again detected in the top horizons.

Many investigators (1, 4, 7) have pointed out the appearance of ascending capillary flow of moisture in spring and early summer in the Cis-Amur and Primor'ye soils. In a dry spring and early summer, when evaporation greatly exceeds precipitation, the melting frost creates favorable conditions for capillary water to rise to the surface of the dried-out soil. Our own observations showed that after the monsoon rains such conditions were again created in undrained fine-textured soils, since evaporation during this period again exceeded atmospheric precipitation while the soil and subsoil waters rarely fell below 60-70 cm in the dry, warm month of September. Rising capillary moisture flow in spring and early summer, as well as in fall (profile 41), make for an accumulation of chloride and ferrous oxide in the top horizons. In drained soils (profile 82) soil and subsoil waters were not detected after the monsoon rains and there were accordingly no ascending flows of capillary moisture in such soils during the fall.

Micromorphological analysis showed that the main body of ortsteins in profile 41 was situated in the top horizons.[5] The reduced iron compounds in the solutions travel along the capillaries to the surface horizons and are precipitated into the layer most subject to drying and aeration (5). In profile 82, ortsteins predominate in the lower part of the soil profile — a clear indication of removal of iron compounds.

The periodical occurrence of ascending capillary flow of moisture accompanied by the migration of reduced iron should account for the fairly even distribution of total iron in the soil profile 41. Conversely, where ascending capillary flow occurs not at all or only to a slight extent, the total chemical

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[4] The sharp decrease in the $SiO_2 : Fe_2O_3$ and $Al_2O_3 : Fe_2O_3$ molecular ratios in the B_1 horizon of profile 82 apparently can be attributed to a podzolization process which may have occurred during a more severe epoch connected with Quaternary glaciation in the Tukuringr-Dzhagda range.

[5] The micromorphological study of the soil's thin sections was performed under the microscope by Ye.I. Parfenova.

Table 6

Seasonal variability of ferrous oxide and chloride in soil solutions and in water extracts

Profile No.	Depth, cm	Soil solutions						Water extract		
		Periods						Periods		
		1		2		3		1	2	3
		Before monsoon-rains		During monsoon-rains		After monsoon-rains				
		Cl^-	Fe^{++}	Cl^-	Fe^{++}	Cl^-	Fe^{++}	Cl^-		
		meq/liter						%		
82	0—10	0,80	1,38	0,20	0,02	0,15	0,05	0,005	0,001	0,001
	12—22	0,40	1,14	0,23	0,02	0,08	0,04	0,002	0,001	Trace
	28—38	0,41	0,51	0,20	0,06	0,08	0,03	0,002	Trace	0,001
	48—58	0,20	0,03	0,28	0,28	0,10	0,18	0,001	0,001	0,001
	75—85	0,30	0,02	0,30	0,03	0,20	0,05	0,001	0,001	0,002
	109—117	0,58	0,10	0,31	0,84	0,75	0,14	0,002	0,002	0,003
41	0—5	0,80	0,37	0,15	0,03	0,75	0,34	0,006	0,001	0,004
	6—11	0,65	0,05	0,20	0,01	0,35	0,06	0,005	0,001	0,003
	12—22	0,50	0,03	0,19	0,30	0,70	0,26	0,004	0,001	0,003
	30—40	0,20	0,02	0,05	0,01	0,20	0,03	0,001	Trace	0,001
	70—80	0,40	0,03	0,28	0,15	0,26	0,02	0,001	0,003	0,001
	120—130	0,72	0,06	1,76	0,17	0,68	0,06	0,002	0,005	0,002

Note: Comma represents decimal point.

composition of the illuvial horizon clearly indicates iron accumulation (profile 82).[6]

All the material examined, then, and in particular our investigation of chemical composition of the soil solutions, point to a different make up of the soil processes in the territory studied than is to be found in a zone of sod-podzolic and podzolic soils. These values convince us that the type of soil formation in the forest soils investigated corresponds mainly to that of the brown forest soils in the Cis-Amur and Primor'ye regions (8).

We must assume that the formation of a differentiated eluvial-illuvial profile in the soils studied (impoverishment of the eluvial horizons in colloidal clay fractions and their enrichment in silica) is a contemporary process, which may be due mainly to the removal of colloidal clay particles from the top soil horizons without preliminary decomposition of the clay minerals, in other words what is known as lessivage formation. As we mentioned previously, the eluvial-illuvial profile in profile 82 could have been caused by podzolization processes at earlier periods.

The most important indicator of lessivage formation of soils is pronounced accumulation of optically orientated clay in the illuvial horizons. Examination of the thin sections from these soils showed that optically orientated clays from various cavities in the soil could be readily traced in the illuvial horizons. The B horizon of profile 82 was the richest in orientated clay and it was in this horizon that the particle-size analysis revealed the sharpest increase in the clay fraction.

As we noted previously, the soil solutions were invariably turbid owing to the presence of colloids or clay in them. Electron microscope study showed that particles of diameter 1-2 μ and smaller predominated in these.[7] The colloidal clay is therefore mobile here and migrates in the soil profile.

The clay particles in the soil acquire a finely dispersed state under the influence of temporarily excess moisture, which creates conditions in which even substances difficult to disperse are reduced and converted into a readily mobile state. The clay particles can be kept in a condition of suspension under the protective influence of organic matter and silica (16). In the soils studied the decisive role seems of necessity to belong to silica as a stabilizer of the colloidal clay particles as they move through the soil profile.

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[6] The frozen horizons in drained soil contain little moisture and so the probability that there will be ascending capillary moisture flow in spring and early summer is negligible.

[7] The electron microscope determination was performed by E.A. Kornblyum in the Physical Chemistry Laboratory, Moscow University Faculty of Soil Science, under the direction of N.G. Zyrin.

A typical feature of the region studied is that there are periods when the soils are excessively wet. Almost 70% of the annual rainfall of 450 mm falls in July and August, during the monsoon. This is also the hottest period, when the mean temperature (July) is 20°C. At this time the soils are excessively wet and intensive reduction processes start to develop in them. We have no space in this paper to discuss the results of studies on the oxidation-reduction regime in the soils; we can imagine that abrupt variations of both processes from spring to fall, and from one year as a whole to another, are typical of the soils studied.

It is noteworthy that in soils where there is no seasonal excessive-wetting (brown forest sandy loams and coarse sandy loam) and where an oxidizing regime predominates, no eluvial horizon appears, either morphologically or analytically.

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RELATIONSHIP BETWEEN FERTILIZER EFFECTIVENESS ON THICK CHERNOZEM IN MOISTURE-DEFICIENT ZONES AND THE AMOUNT OF PRECIPITATION

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Crop yields depend largely on meteorological conditions. Several authors (2, 3, 6, 8, 10, 12) adduce figures to show that the decisive factor in humid regions is the air temperature during the growth period; but in regions of moisture deficiency the yield is usually determined by the amount of precipitation which has fallen during the growing period. It is not only the amount, but also the distribution of precipitation over the different periods which plays an important part in ensuring normal growth of the plants and producing a high yield. The critical periods as regards moisture are not the same for all crops.

The optimum conditions for the growth of all crops is that there should be sufficient precipitation throughout the growing period. Different crops will be differently affected by moisture deficiency at various periods. The yield of some crops is reduced if there is drought during the first half of summer, but the yield of late crops may not be reduced if the second half of the summer is wet; conversely an amount of precipitation falling in the first half of the growing period and ensuring a high yield of early crops may adversely affect yields of late crops if there is a sudden drought in the second half of the summer.

The effect of fertilizers is also bound up with the presence of sufficient moisture in the soil when the plants are feeding most intensively (1, 7); such periods differ from different plants. If there is insufficient soil moisture during these periods fertilizers will be less effective, since the plants' uptake of soil solution containing them will be poor and all physiological processes will be weakened owing to the moisture deficiency. Sometimes, owing to lack of moisture at a later period, the effect of fertilizers on the final yield may be negative (plants which have developed strongly under the influence of fertilizers suffer worse than those in non-fertilized soil). Fertilizers can also have an adverse effect on grain crops if there is excess moisture when fertilized plants are strongly set in the flowering of grain-forming stage, for the grain formation then takes place under unfavorable conditions. This means that the selector must choose varieties which are resistant to lodging, in order to improve the effectiveness of fertilizers in regions of abundant precipitation or where grain crops are cultivated under irrigation.

The importance of meteorological conditions at various periods of plant growth is fairly clearly illustrated by the data on the effectiveness of fertilizers during the initial period of growth and at the end of the growing period in the case of sugar beet (Table 1).

These values show that nitrogen phosphate fertilizers invariably produce an appreciable increase in the weight of the air dry young plants; in certain years, although the initial effect is high, the increase in root yield is negligible when there is insufficient precipitation in summer. In 1955, for example, when the weight of the young plants increased by 78% and 306 mm of rain fell during the period May-August, the root yield increased by 100 centners per ha, whereas in 1957, when the weight of the young plants increased by 169% but precipitation during the period May-August was negligible (117 mm), the root yield increased only by 11 centners per ha.

The effectiveness of fertilizers when their influence during the initial period of plant growth is positive thus depends greatly on meteorological conditions during the growing period after the beet shoots have been thinned. It is noteworthy that no strict correlation has been observed between the amount of precipitation during a particular period and the yield of particular crops, or between the effectiveness of fertilizers from one year to another, since other meteorological indices (distribution of precipitation, air temperature, relative air humidity and others) also influence the yield; nevertheless the level of yield and the effectiveness of fertilizers are closely bound up with the amount of precipitation during a given period, as can be seen from the average values, given below, for experiments performed over a number of years at the Grakovskiy experimental field of the Scientific Institute for Fertilizers, Insecticides, and Fungicides. Data on the yields of particular crops and the effectiveness of fertilizers are given below.

Sugar Beets

The harvest yields over a number of years

Table 1

Effectiveness of fertilizers during the initial growth period of sugar beets and their influence on final yields

Year	Weight of 200 plants taken during thinning, g		Increment	
	Without fertilizer	With N P	Weight of young plants, %	Root yield, cntr per ha
1950	9,5	11,0	16	17
1951	13,3	20,7	56	34
1952	11,3	15,5	37	12
1953	19,2	26,3	37	32
1955	11,4	20,3	78	100
1956	9,4	21,6	130	67
1957	49,0	132,0	169	11
1958	32,9	65,9	100	61

Note: Comma represents decimal point.

Table 2

Yield of sugar beet roots and increments from phosphorous fertilizer, centners per ha

Type of year	No. of years	Mean total precipitation during May-August, mm	Yield with NK	Increments from	
				P_{super}	$P_{gr. rock}$
Insufficient precipitation	7	152,0	212	23	19
Wet	6	245,9	270	34	27

Note: Comma represents decimal point.

show that the best yield is determined by the amount of precipitation during the period May-August.

It can be seen from Table 2 that both the yield and the effectiveness of phosphates were higher in years when precipitation during those months was heavy than in years when it was not.

In years of inadequate precipitation nitrogen fertilizers applied after phosphorus and potassium had almost no effect on the sugar beet yield, whereas in wet years the increment from nitrogen amounted to 25 centners per ha. The pattern in regard to manure was similar but less pronounced, the increment from application of 33 metric tons of manure per ha being 40 centners per ha above the control (no fertilizer) in dry years, and 53 centners per ha in wet years.

In regard to nitrogen and phosphorus the picture is the same whether they are added simultaneously or separately: the mean effectiveness of nitrogen phosphate fertilizers as shown from two experiments in wet years was 40 centners per ha, against 24 centners per ha in dry years.

The effectiveness of potassium fertilizers was poor in a number of years when the amount of precipitation during May-August varied and was the same in wet and in dry years. However, if the years are classified by amount of precipitation during April-June, in other words during the initial growth period of the sugar beets (Table 3), the effect is found to have varied considerably, for in dry years the potassium fertilizers were ineffective, whereas in wet years they produced an appreciable increment to the root yields.

This is obviously because the plants absorb potassium at a greater rate when they are young. Sugar beets take up potassium throughout its growth period, but in the later stages their powerful root system supplies it with potassium via the exchangeable form of that element, which occurs at the rate of 30 mg per 100 g of soil in the plow layer of our thick chernozem.

The effectiveness of organic and mineral fertilizers added under sugar beets is thus largely dependent on the amount of precipitation

Table 3

Yields of sugar beets and increments from potassium, centners per ha

Type of year	No. of years	Mean total precipitation, April-June, mm	Yield with NK	Increment from potassium				
				KCl	K_2SO_4	Sylvinite	Carnallite	Average
Insufficient precipitation	7	84,5	239	1	1	0	7	2
Wet	7	168,0	295	9	12	17	12	12

Note: Comma represents decimal point.

throughout the growth period; in the case of nitrogen and phosphorous fertilizers the critical period as regards moisture is May-August; in the case of potassium fertilizers the critical period is April-June.

Barley

Examination of the yield data for barley over a number of years shows that the critical period in regard to moisture for this crop coincides with the period of peak uptake of nutrients (1,7). Under the conditions in question this period is the month of May.

The data on barley grain yield and additions of nitrogen, phosphorous and nitrogen-phosphorous fertilizers given in Table 4 show that the yield without fertilizers and the effectiveness of the fertilizers depend on the amount of precipitation in May, when the barley is growing fastest and the spikes are forming. When there is little precipitation during this period we find that the grain harvest is low if no fertilizer is added and that the effect of fertilizers, particularly nitrogen, is reduced. A sufficient amount of precipitation during the following period, before the barley ripens, is not in itself able to increase the yield or the effectiveness of the fertilizers. This indicates that May itself is the critical month in regard to moisture for this crop.

Winter Wheat

The growth period for winter wheat includes the autumn months in the year of sowing and the spring summer months in the year of ripening. The yield of winter wheat sown on black fallow varies little with the amount of precipitation. This is because there is always a considerable amount of moisture in black fallow, even in years of inadequate precipitation. In such years the wheat yield amounts to 24 centners per ha, whereas in wet years the wheat as a rule lodges before the formation of the grain, and this reduces the yield. The effectiveness of phosphorus during years with inadequate precipitation under black fallow conditions is reduced to zero, whereas in wet years, despite reduced efficiency from lodging, the increment amounts to 2 centners of grain per ha.

The behavior of potassium fertilizers is rather peculiar. On the average, these increase the grain yield of winter wheat by 2

Table 4

Yields of barley and increments from fertilizers, centners per ha

Type of year	No. of years	Mean total precipitation in May, mm	Yield			Increments from		
			Without fertilizer	With		N	P_2O_5	NP
				P_2O_5	N			
Insufficient precipitation	6	17,0	—	16,5	—	2,8	—	—
Wet	4	57,4	—	19,5	—	6,0	—	—
Insufficient precipitation	5	19,2	—	—	13,4	—	3,8	—
Wet	5	58,5	—	—	17,5	—	5,0	—
Insufficient precipitation	7	19,0	11,1	—	—	—	—	5,6
Wet	6	57,0	19,1	—	—	—	—	7,3

Note: Comma represents decimal point.

centners per ha. No regular pattern of relationship between the effectiveness of potassium and the amount of precipitation can be observed, but potassium has a clear-cut positive effect in years unfavorable for winter wheat, when there is marked lodging of the crop as a result of abundant precipitation, or in dry years, with periods of drought, when the wheat is subject to firing.

The mean yields for four bad years shown in Table 5 (in two of these years the wheat lodged heavily and in the other two it suffered from drought at the moment of grain filling) together with the mean yields for five years of more or less normal growth, indicate that in normal years potassium produces negligible increments to the yield; in bad years, however, the increment amounts to 4.2 centners per ha.

Potassium fertilizers applied to black fallow are thus seen to be a stabilizing factor as regards winter wheat yields in bad years.

Relative Role of Moisture and Fertilizers As Regards Particular Crops

In order to provide a comparison between the role of moisture and that of fertilizers in regard to particular crops, we show in Table 6 the mean yields for three experiments on sugar beets and barley.

The data show that the yield of both crops was appreciably higher in wet than in dry years. The effectiveness of nitrogen phosphate fertilizers in wet years was a good deal higher than in dry years, particularly when the fertilizers were added under sugar beets (49 and 22 centners per ha).

Although fertilizers also had a positive effect in dry years, the sugar beet yield with fertilizers still did not reach the same level as in wet years when no fertilizers were added. This implies that moisture is the deciding factor in forming the sugar beet yield; in dry years the barley yield with fertilizer was the same as in wet years without fertilizer.

Maximum yields for sugar beets as well as for barley were obtained in wet years when fertilizer was added, that is, when the plants were fully supplied both with moisture and with nutrients.

That moisture and fertilizers are of different importance in forming sugar beet and barley yields is further confirmed by the data for the influence of fertilizers on the yield stability of these crops.

The data in Table 7 do not bear out the observations of the Kharkov and Suma experimental stations (1) to the effect that the yield stability of sugar beets is enhanced by the addition of fertilizers. In the case of barley, however, variations in the grain yields from crops fertilized with NPK as compared with nonfertilized crops were found to be distinctly smaller.

The data available in the literature (4, 5, 9) in regard to the importance of soil temperature during the initial growth period of spring crops (April-May) or the effectiveness of fertilizers are not borne out under our conditions when the mean diurnal air temperature during these months is 11.1°C. In the case of sugar beets, for example, the yield increment associated with a positive deviation of the mean diurnal air temperature averaged 28 centners per ha over a period of five years, against 30 centners

Table 5

Yields of winter wheat and increments from potassium, centners per ha

Year	No. of years	Yield with NP	Increment from K	Yield with NAK
Bad	4	22,5	4,2	26,7
Good	5	25,9	0,9	26,8

Note: Comma represents decimal point.

Table 6

Yields of sugar beets and barley, centners per ha

Crop	Dry years			Wet years		
	No. of years	Yield		No. of years	Yield	
		Without fertilizer	With NP		Without fertilizer	With NP
Sugar beets	21	222	244	19	272	321
Barley	18	12,0	17,7	15	17,5	24,8

Note: Comma represents decimal point.

Table 7

Variations in sugar beets and barley yields

Crop	Fertilizers	Experiment 3			Experiment 7		
		No. of years	Yield cntr. per ha	Ratio	No. of years	Yield cntr. per ha	Ratio
Sugar beets	Without fertilizers	16	85—342	1 : 4,0	15	116 : 309	1 : 2,7
Barley	NPK		107—421	1 : 3,9		143 : 375	1 : 2,6
	Without fertilizers	16	5,2—28,5	1 : 5,5	12	4,1—29,1	1 : 7,1
	NPK		9,5—33,1	1 : 3,5		8,4—29,9	1 : 3,6

Note: Comma represents decimal point.

per ha over a period of three years when the temperature deviation was negative; in the case of barley, the corresponding increments from nitrogen were 3.6 and 8.1 centners of grain per ha. respectively; the difference in the case of barley was due not to temperature but to variations in the amount of precipitation during May.

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SUITABILITY OF SOILS OF THE SECOND VOLGA MEADOW TERRACE FOR ORCHARDS

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The right choice of soil and relief is of decisive importance for the establishment of productive and perennial fruit-tree orchards. High standards of agricultural technique yield the desired results only if there are no unfavorable indications in regard to the soils. Orchards planted on soils which do not meet the crop requirements are not easily preserved from premature death. It often happens that the orchard does not die at once but only after ten to fifteen years. This leads to uneconomical expenditure.

The Stalingrad Fruit and Vegetable Experimental Breeding Station is engaged in studying the suitability of soils of the second Volga meadow terrace for orchards (in this region the other terraces are not expressed).

This terrace consists of a fairly wide belt on the right bank of the Volga River in the Chernoyarsk rayon of the Astrakhan Oblast'. From the geomorphological point of view it occupies an intermediate position between the main bank of the river and its bottomland and forms a plain with a very pronounced micro-relief. The main bank of the Volga rises above it, forming a 10-12 m escarpment. The edge of the terrace towards the bottomland is 2-3 m higher than this escarpment.

The depth of the ground waters varies with the season of the year and the relief. They are deepest (5-9 m) under the sandy hillocks and least deep (1.8-2.5 m) under depressions and estuaries. Elsewhere in the area the ground waters lie below 2.5-3.0 m.

We have used P. G. Shitt's method to investigate agricultural soil and biological conditions in the irrigated orchards of the Mikoyan State Farm and Kalenin Collective Farm in the Chernoyarsk rayon of the Astrakhan Oblast'.[1]

The main purpose of the investigation was to find the reactions of fruit trees to the combination of conditions prevailing on the sites where they grow. This meant primarily the soils, the relief, the climate, the water regime, and other factors.

The agricultural biological part of the investigation covered the following questions: 1) study of the growth conditions of the fruit crops from the moment of preparing the soil under the plantation; 2) evaluation with subsequent selection of plot (typical) areas; 3) state of the trees and their separate organs, including the root system, in the plot area, and 4) growth and fruit-bearing of branches.

Soil and root profiles were prepared on the plot area, with one of their lateral walls at a distance of 50-70 cm along the perpendicular from the tree trunk. The following operations were performed in these profiles: a) prolonged morphological description of the soil profile to a depth of 200 cm; b) a root survey; and c) soil and ground water (when present) were sampled.

At the Mikoyan State Farm, orchard stand numbers 17, 18, 19, 21 and 22 and the Monastyr and Grachev orchards (Fig. 1) were investigated in detail as were the Kalenin Collective Farm and the Trudovskoy and Stakhanovskiy orchards.

The soil in the orchard sectors is made up of a combination of the following soil groups and types:

I. Brown soils

1. Slightly solonetzic
2. Solonetzic
3. Solonetzic-solonchakized
4. Solonetzic-solonchak-like (G. M. Tumin's method)
5. Eroded non-saline
6. Eroded solonchakized

II. Dark soils

Slightly solonetzic and solonetzic brown soils usually occupy level areas and slight slopes. They cover the greatest area in all the Kalenin State Farm orchards and stands 19, 21, and 22 at the Mikoyan Collective Farm.

The profile of the solonetzic soil is made up of a humic, usually structureless A horizon

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[1] The work was directed by A. S. Devyatov and the soil research was performed by G. A. Selezneva. The analyses were performed by G. A. Selezneva and V. M. Glukhova.

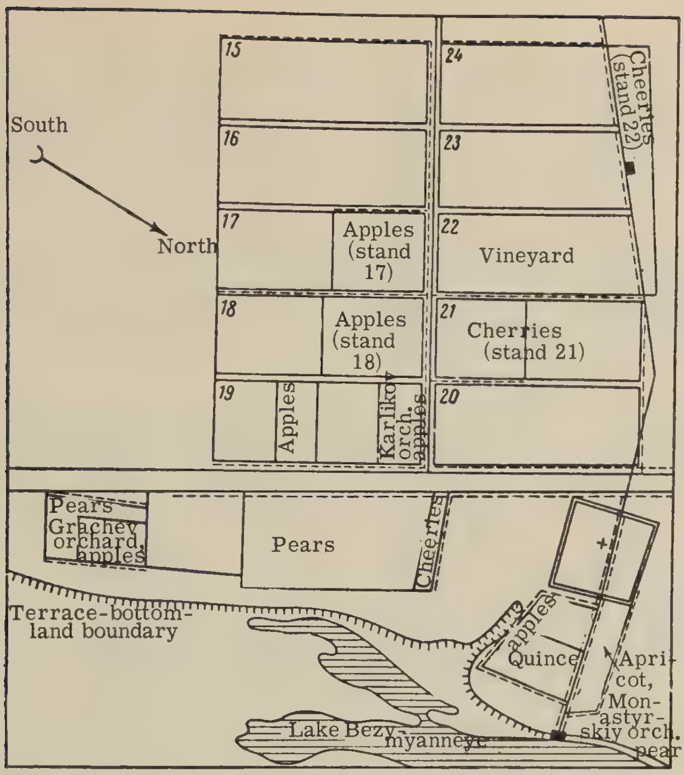

Fig. 1. - Plan of fruit-tree orchards at the Mikoyan State Farm.

10-15 cm thick, under which there is a distinct, compact, brown and cinnamon-brown solonetzic B horizon sometimes consisting of two subhorizons, B_1 and B_2. Below this again is a carbonate C horizon, with transition to old alluvium. Effervescence starts at a depth of 20-35 cm.

The slightly solonetzic brown soils have a structure similar to that described previously but differ from these in that the B horizon is less compacted, the effervescence depth is lower, and the texture is coarser.

Soil formation on the small rises, which are usually without any kind of vegetation is of quite a different character. The soils that form here are solonetzic-solonchak-like brown. The profile is made up of a friable porous A horizon, under which is solonetzic B horizon, and under that again a saline C horizon. Typical features of these soils are the considerable thickness (25-30 cm) and reddish-brown color of the A horizon, the friable structure (except for the solonetzic B horizon) and the salt efflorescence. In those parts which are occupied by solonetzic-solonchak-like soils, apple trees failed almost completely (stands 17 and 21).

The solonetzic-solonchak-like brown soils (Tumin method) are similar in properties to the solonetzic brown, from which they differ in having salt efflorescence below 80 cm. The separation of this soil is of great importance in connection with the suitability of brown soils for orchards. The solonetzic-solonchak-like soils occupy small areas in stand No. 19. The apple trees in these parts are weak and are either diseased or fail completely.

In the Grachev orchard, situated on a terrace sloping comparatively gently towards the bottomland, half a kilometer north of the main bank of the Volga, the soils are brown and severely eroded. The soil profile consists of an alternation of light-colored layers of coarse-textured old alluvium. Most of these soils are salinized.

The ground waters lie at a depth of more than 2.5-3.0 m.

Effervescence has been observed throughout the profile.

Dark soils form in the pronounced depressions where additional amounts of moisture collect. These are distinguished by their greater thickness (35-46 cm), the dark color of the A horizon and the lower effervescence depth (85-90 cm). The ground (fresh) waters lie at a depth of 175-250 cm. The soils are not saline and have a limited distribution (in the central part of the Trudovskoy orchard and in stand numbers 17 and 18).

In texture, these soils differ appreciably

Table 1

Particle-size analysis of main soils in meadow terrace orchards, %

Profile No.	Location of profile, soil and fruit-trees	Horizon and layer	Depth, cm	Losses from pretreatment, %	Particle diameter, mm						Content of part. <0.01 mm in diam.
					1,0—0,25	0,25—0,05	0,05—0,01	0,01—0,005	0,005—0,001	<0,001	
101	Mikoyan State Farm. Slightly solonetzic br., stand 22, Rastun'ya cherry, 25/13	A_1	0—20	1,0	5,06	68,24	14,20	2,52	1,66	8,32	12,50
		B_1	30—50	1,02	5,94	52,42	26,14	1,97	4,57	8,96	15,50
		C_1	60—75	6,84	5,51	69,75	11,09	3,96	8,12	1,57	13,65
		C_2	85—100	3,68	None	32,76	43,70	6,44	10,74	6,36	23,54
88	Slightly solonetzic brown, stant 17, Maltbagaevski apple, 3/18	A_1	0—10	4,26	5,42	29,51	16,34	8,87	15,73	24,13	48,73
		A_2	11—15	2,00	3,23	21,68	61,03	1,80	0,89	11,37	14,06
		B_1	16—36	2,84	1,94	33,53	37,50	10,80	5,14	11,09	27,03
		C_1	37—97	5,36	None	31,94	34,27	15,77	1,78	16,24	33,79
		C_2	98—143	5,82	0,68	44,52	33,39	7,09	1,40	12,92	21,41
		6	144—164	6,00	0,35	6,94	33,10	29,46	4,51	25,64	59,61
		7	165—190	5,80	None	44,58	28,49	6,32	7,20	13,41	26,93
89	Solonetzic-solonchak-like brown, stand 17, dead apple trees	A_1	0—26	2,92	1,29	30,84	43,81	6,34	8,57	9,15	24,06
		B_1	27—48	2,72	0,70	26,76	48,61	7,85	5,51	10,57	23,93
		C	49—81	8,74	0,21	39,49	40,44	7,15	3,41	9,30	19,86
		4	82—141	6,04	None	46,06	32,37	3,92	7,50	10,15	21,57
		5	142—170	6,52	0,38	30,76	39,52	9,09	10,20	10,05	29,34
		6	171—185	3,54	0,66	16,94	65,34	0,55	5,73	10,78	17,06
81	Solonetzic-solonchak-like brown, stand 19, Lithuanina pippin apple, 2/16	A_1	0—10	4,05	0,96	45,85	23,71	8,16	3,63	17,69	29,48
		B_1	11—18	4,00	3,64	34,58	36,67	1,91	0,71	22,49	25,11
		C_1	19—45	11,72	1,32	39,28	33,39	5,31	1,27	19,23	26,01
		C_2	46—102	4,20	1,18	36,02	38,48	5,42	2,64	16,27	24,33
		C_3	103—142	3,83	1,50	38,50	31,82	8,10	2,23	17,85	28,18
		D_3	142—200	4,05	0,51	17,37	2,72	24,07	15,00	40,33	79,40
114	Grachev orchard, eroded solonchak-like br., gray anise apple, 13/7	2	15—50	7,00	14,31	45,31	17,87	10,68	3,90	7,93	22,51
		3	60—80	0,56	None	86,82	4,22	1,41	2,85	4,70	8,96
		4	90—180	4,24	"	57,27	29,63	2,66	4,86	5,58	13,10
		5	190—213	5,82	"	23,45	38,26	22,71	6,78	8,80	38,29
127	Kalenin Collective Farm, Trudovskoy orchard. Dark soil. P'yanushka apple, 8/32	A_1	0—19	1,89	None	25,59	42,48	10,77	11,69	9.47	31,93
		A_2	20—49	5,00	"	29,66	13,27	42,44	4,87	10,16	57,07
		B_1	50—84	1,81	0,54	14,86	53.06	6,83	7,54	17,17	31,54
		C_1	85—112	6,84	None	41,13	40,87	11,24	1,33	5,43	18,00
		C_2	113—149	7,18	0,91	23,16	46,36	7,47	6,12	15,98	29,57
		7	193—213	0,80	1,13	39,04	34,57	3,84	0,56	20,86	25,26

Note: Comma represents decimal point.

from one another (Table 1). The amount of humus in the brown soils rarely exceeds 1%. In the dark soils it increases to 2.39%. Sodium ion is important among the exchangeable cations in the solonetzic brown soils (14.2% of the total cation content). In the slightly solonetzic soils the sodium ion content is 5.6%-7.8%.

The slightly solonetzic brown soils are usually not saline. They contain about 0.2% of water-soluble salts. The solonetzic soils vary greatly in regard to salt content. Near depressions they are well leached but in level areas they pass into solonetzic-solonchak-like types containing up to 1.78% salts in the second meter of soil, mainly sulfates (Table 2).

The most salinized are the solonetzic-solonchakish soils. The predominant salts are chlorides. In profile 89 for example the chloride ion content varies from 0.13% to 0.54%

Table 2

Analysis of water extracts from soils investigated

Profile No.	Soil	Horizon and layer	Depth, cm	Dry residue, %	%					Meq				
					Total alkalinity	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}	Total alkalinity	Cl^-	$SO_4^=$	Ca^{++}	Mg^{++}
89	Solonetzic-solonchakish brown	A	0—26	0,500	0,010	0,240	0,050	0,133	0,004	0,16	6,86	1,25	6,67	0,30
		B	26—43	0,576	0,015	0,258	0,062	0,065	0,005	0,24	7,35	1,28	3,24	0,41
		C_1	48—81	1,165	0,018	0,538	0,176	0,256	0,017	0,29	15,38	3,65	14,81	1,37
		C_2	81—141	0,991	0,030	0,324	0,281	0,229	0,008	0,45	9,25	5,85	11.54	0,68
		C_4	171—185	0,618	0,022	0,131	0,254	0,119	0,016	0,36	3,70	5,49	5,92	1,30
85	Solonetzic-solonchak-like brown	A	0—15	0,155	0,026	0,003	0,065	0,024	0,005	0,42	0,10	1,35	1,20	0,44
		C_1	28—58	0,163	0,030	0,003	0,076	0,025	0,005	0,45	0,07	1,58	1,26	0,41
		C_3	75—93	0,379	0,024	0,046	0,099	0,070	0,002	0,39	1,31	2,07	3,48	0,13
		C_4	93—145	1,780	0,011	0,103	1,094	0,491	0,010	0,18	2,93	22,78	24,53	0,84
81	Same	A	0—10	0,103	0,046	0,001	0,022	0,010	0,002	0,76	0,03	0,47	0,50	0,20
		B	10—18	0,141	0,057	0,006	0,041	0,021	0,002	0,93	0,15	0,85	1,07	0,13
		C_1	18—45	0,188	0,043	0,004	0,094	0,021	0,005	0,70	0,11	1,95	1,73	0,41
		C_2	45—102	0,097	0,018	0,003	0,044	0,019	0,003	0,29	0,09	0,90	0,99	0,23
		C_3	102—142	0,128	0,006	0,008	0,068	0,031	0,002	0,10	0,21	1,41	1,67	0,01
		D	142—200	1,435	0,030	0,012	0,916	0,360	0,017	0,47	0,32	19,07	18,00	1,37
104	Eroded non-saline brown	1	0—21	0,156	0,040	0,008	0,056	0,030	0,005	0,66	0,22	1,16	1,51	0,37
		2	22—37	0,179	0,027	0,010	0.065	0,024	0,004	0,43	0,27	1,35	1,21	0,33
		4	94—136	0,156	0,062	0,011	0,055	0,032	0,003	1,02	0,30	1,15	1,60	0,26
		5	137—200	0,179	0,048	0,015	0,062	0,021	0,008	0,77	0,42	1,28	1,05	0,63
111	Eroded solonchakish brown	1	0—25	0,916	0,029	0,026	0,067	0,031	0,008	0,47	0,73	1,40	1,52	0,67
		2	30—48	0,143	0,022	0,006	0,075	0,028	0,008	0,35	0,15	1,17	1,37	0,63
		3	50—61	0,453	0,026	0,061	0,223	0,063	0,009	0,43	1,73	4,61	3,12	0,75
		4	62—71	0,916	0,023	0,096	0,479	0,180	0,007	0,38	2,74	9,97	8,95	0,53
		5	72—128	1,330	0,034	0,101	0,742	0,237	0,009	0,55	2,88	15,40	11,30	0,75
114	Same	2	15—20	0,286	0,050	0,038	0,063	0,050	0,002	0,82	1,08	1,32	2,51	0,12
		3	60—80	0,398	0,042	0,084	0,112	0,039	0,003	0,69	2,39	2,33	1,94	0,26
		5	190—213	1,061	0,044	0,084	0,593	0,149	0,009	0,72	2,40	12,34	7,43	0,75
127	Dark	A_1	0—19	0,095	0,018	0,006	0,036	0,013	0,002	0 30	0,17	0,76	0,66	0,16
		A_2	19—49	0,128	0,017	0,005	0,069	0,177	0,004	0,27	0,13	1,43	0,86	0,33
		B	49—84	0,092	0,037	0,006	0,041	0,024	0,002	0,62	0,17	0,84	1,21	0,12
		C_1	84—112	0,066	0,043	0,008	0,018	0,015	0,002	0,72	0,21	0,36	0,73	0,20
		C_2	112—149	0,095	0,034	0,009	0,041	0,021	0,003	0,60	0,25	0,85	1,05	0,27
		C	193—213	0,141	0,031	0,018	0,068	0,028	0,010	0,51	0,52	1,40	1,12	0,85

Note: Comma represents decimal point.

(Table 2). The dark soils are practically nonsaline.

The active reaction of the soils described is neutral or slightly alkaline (7.0-7.8). All the soils of the meadow terrace are rich in available potassium. In the brown soils the potassium content varies from 24.0 to 60.0 mg, in the dark soils from 48.0 to 60.0 mg per 100 g of soil. The potassium amount gradually decreases with depth. There is considerably less available phosphoric acid — 13.7 to 20.0 mg per 100 g of soil in the brown soils and 12.0-50.0 mg in the dark soils. Available phosphates are fairly evenly distributed throughout the profile.

The main fruit trees on the land under study are apples and cherries. Table 3, based on the orchard evaluation data, shows the state of the trees in relation to soil conditions. Comparing the behavior of different

Table 3

Condition of trees in meadow terrace soils

Soil	Location of profile	Tree species	Year of planting	No. of trees	No. of trees, percentage scale				No. of failures
					5	4	3	2+1	
Solonetzic fine clay loam brown	Mikoyan State Farm stand 17, profile 88	Apple	1933	150	0,7	8,0	18,6	15,3	57,3
Slightly solonetzic coarse clay loam brown	" Profile 90	"	"	69	24,6	30,4	11,6	11,6	21,7
Solonetzic-solonchakish coarse clay loam brown	" Profile 89	"	"	192	0	0	0,5	0,5	98,9
Solonetzic brown	" Stand 22 Profile 102	Cherry	1949	147	4,7	36,0	32,6	6,7	19,7
Slightly solonetzic sandy loam brown	" Profile 101	Same	"	158	35,2	32,1	17,8	1,5	12,4
Eroded solonchakish coarse clay loam brown	Grachev orchard, Profile 114	Apple	1922	323	0	0	4,6	3,5	91,9
Same	" Profile 111	Pear	"	74	10,0	50,0	20,0	1,4	17,6
Solonetzic sandy loam brown	Collective Farm, Trudovskoy orchard, Profile 125	Apple	1936	107	0	1,9	17,7	8,4	72,0
Dark clay loam, ground waters below 2 m	Same, Profile 127	Same	"	100	40,0	42,0	11,0	0	7,0
Same, ground waters above 1.8 m + flooding from thaw waters	Mikoyan State Farm, Stand 18, Profile 93	"	1932	77	0	0	3,9	2,6	93,5

Note: Comma represents decimal point.

kinds of trees in plots with different soils but identical cultivation, we find that apple trees are the most sensitive to soil conditions.

The influence of soil can be seen very clearly in the case of stand No. 17. The main part of the orchard was laid down in 1933, with gray anise and Mal't bagaevski apples. By 1935 the entire southern half and part of the northern half had failed. Later, the northern half was replanted, but despite irrigation the trees again failed. The stand was divided into five sectors, on the basis of a soil survey and tree evaluation (Fig. 2). Here the sharp difference in the condition of the apple trees depends primarily on the soil conditions, which vary greatly.

Variations in the soil have an immediate effect on the life of the trees. 98.9% of the apple trees on the solonetzic-solonchak-like soils (Fig. 2, plot 2, profile 89), containing about 1.5% of salts, failed. Those on solonetzic-solonchak-like brown soil (Fig. 2, plot 5) suffered heavily, only 8.7% of the trees developing properly and 57.3% failing completely. Observation showed that in the solonetzic soil the roots of the apple trees for the most part extended for 20-60 cm, hardly penetrating at all into the lower layers.

Apple trees on slightly solonetzic brown soil (plot No. 3) did better, the percentage of healthy trees amounting to 66.4. The root system here penetrated the second meter of the soil.

Taking stand No. 17 as an example it is interesting to trace the variation in the state of the trees in relation to soil conditions. Those in the fourth row for example (1, 3, 4) are situated at successive points of the transition to a dark slightly solonetzic brown and a solonetzic-solonchak-like soil, and the condition of the trees deteriorates with the properties of the soils (Table 4).

The growth of the apple trees on the eroded soils depends on the degree of salinization of the soils. On eroded nonsaline (Table 2, profile 104) soil of coarse texture in the Monastyr

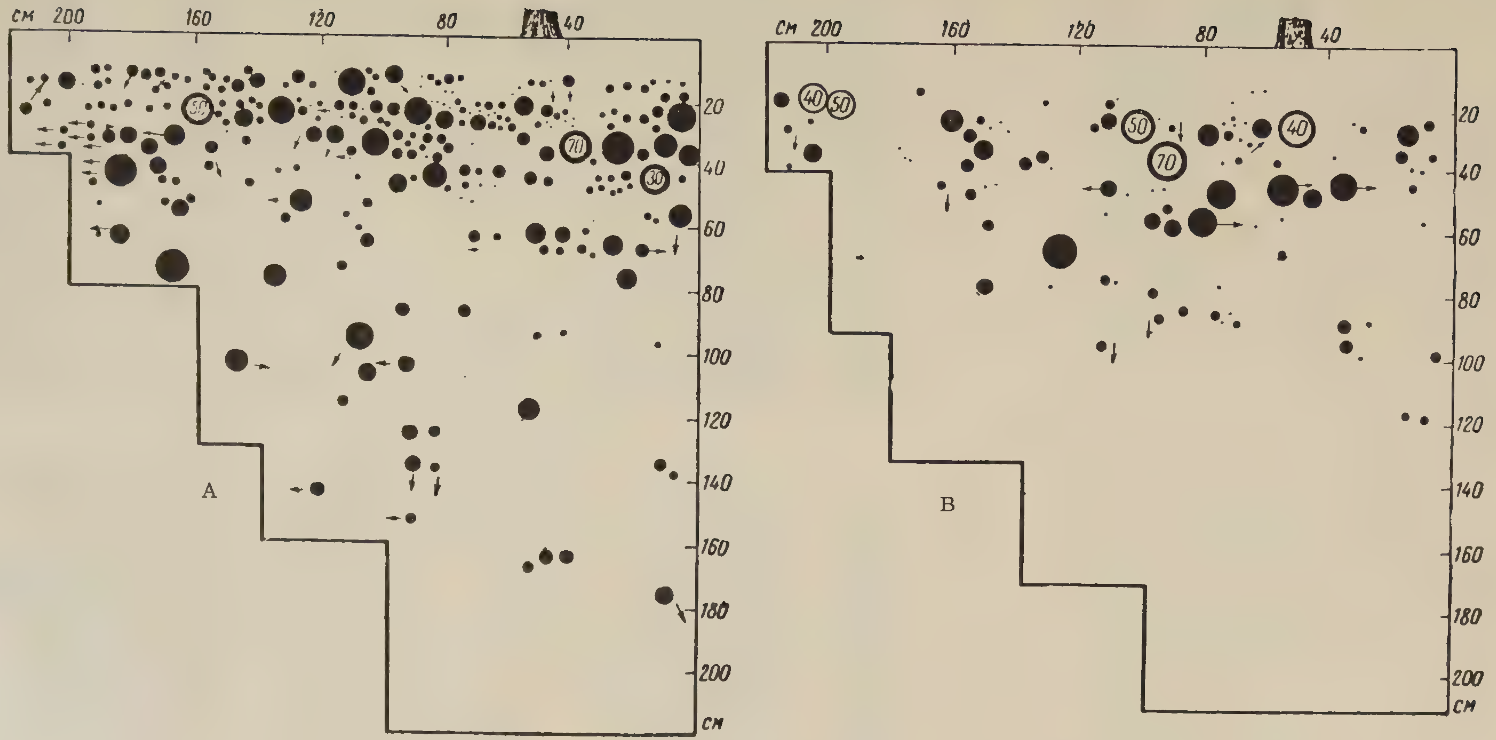

Fig. 2. - Development of pears and apple tree roots in eroded solonchak soil in Grachev orchard. A - profile 111. Pear 3/3, age 34 years, condition satisfactory; B - profile 114. Gray anise apples 13/7, age 25 years, tree diseased, withered.

Table 4

Condition of trees as a function of variation of soil conditions

Mal't bagaevski apple Tree No.	Life span	Height of tree, m	Diameter of crown, m	Circumference of trunk, cm	Crown withering	Apple-tree cancer (Sphaeropsis malorum)	Foliation
4/1	F[a]	5,6	8,1	79	Nil		Weak
4/3	F	7,2	8,3	71	"		Normal
4/4	F/W[b]	4,8	7,2	70	Strong	Medium	Weak
5/1	F	6,9	8,9	84	Nil		Good
5/2	F	6,3	9,5	99	Good	Nil	"
5/3	F	4,6	7,2	59	Nil	Medium	"
5/4	F/W	4,0	4,7	54	Medium	Medium	"

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[a] Fruit-bearing

[b] Fruit-bearing and withering

Note: Comma represents decimal point.

orchard, apple and pear trees survived for seventy years. On eroded solonchak soils of coarse texture in the Grachev orchard (Table 2, profile 111, 114) 92% of the apple trees failed and no healthy trees were found.

Pear trees behaved quite differently under these conditions. 81% of them grew strongly, with good foliation. Most of the trees in the orchard were grafted with Bergamot, Lever, Limonnaya and Kislovka varieties. The following table shows the variation of increments of branches in the case of 3/17 Kislovka pears:

	1944	1945	1946	1947	1948	1949	1950	1951	1952	1953
	19									
Primary branch	2	28	30	3	19	34	1	19	1	12
Secondary branch	1	2.5	3	3	30	1	1.5	2	1	0.5
Leader	3	3	2	9	2.9	2.5	49	2	4	6

The growth pattern of other pear trees was similar. Consequently, despite the good growth and resistance of the pear trees to salinization and drought, they entered into a period of fruit-bearing and withering in the course of thirty-three years (the life periods according to P.G. Shitt).

In order to study the root distribution in the case of apple and pear trees in the Grachev orchard, we dug two concentric trenches, two meters deep and one meter wide, representing a one-eighth arc around the trunk, in addition to digging the usual soil-root profiles. The near wall of the first trench was 1 m from the tree, that of the second trench 3 m. The excavations produced perpendicular walls, 1, 2, 3, and 4 m from the tree. This method of studying the root system, which was first introduced by us, gives more accurate results than digging a half quadrant around the trunk, since it enables one to establish precisely the disposition of the roots as regards both radius and depth; it also appreciably speeds up the work and is economical of money and manpower.

Investigation showed that the root system of the apple and pear trees on the eroded solonchak brown soil developed unevenly. In the case of the pear trees, the root system extended to a depth of more than 2 m at a distance of more than 4 m from the trunk. The largest amount of roots was found at a distance of 2 m from the tree. It was characteristic that pear tree roots were found in large quantities in the saliniferous layers as well (Fig. 2, A).

In the case of the apple trees the roots were mainly at a depth of 20-60 cm. There were few roots even 3 m away from the tree and none 4 m away. The roots did not penetrate the saliniferous layers at all (Fig. 2 B).

In the Grachev orchard 92% of the apple trees but only 17.6% of the pear trees failed. 80% of the latter were healthy. Pears, then, fluorish under conditions in which apple trees normally cannot develop.

Apple trees grow very well, however, in dark soil in depressions where the ground waters are at a depth of more than 2 m. The root system is thick and even at a depth of 210 cm (profile 127, Trudovskoy orchard, P'yanushka apples, 8/32) many skeletal and overgrown roots are found. The central part of the Trudovskoy orchard (Kalenin Collective

Farm) is characterized by dark soil, with ground waters 2 m below the surface. The whole soil profile is evenly moistened. Of 100 trees planted in 1936, 93 were healthy. The condition of the apple trees in solonetzic soil in the same orchard was quite different; 71.9% of them died.

It is interesting to compare data on the development of the root system in different soils but with identical methods of cultivation in the Trudovskoy orchard.

As Table 5 shows, the root system of the apple trees developed best on dark soil. Here the roots were most compact in the first meter of soil. Development of the root system was much weaker in slightly solonetzic coarse clay loam, where the main body of the roots was concentrated in the 10-50 cm layer. In solonetzic soil the roots did not penetrate into the more compact layers. The largest quantity of roots was found in the 30-50 cm and 150-190 cm layers.

These data graphically reflect the reaction of apple tree roots to different properties of the soil. An orchard on dark clay loam, where the water stands in the spring (sometimes for about a month) and the ground waters (fresh) lie at a depth of 175 cm in summer (without irrigation), has become a waste land (western part of stand No. 18 in the Mikoyan State Farm). 93% of the apple trees planted in 1932 perished from excessive moisture.

The apple trees on a plot of dark soil in stand No. 17, which is a continuation of stand No. 18, where the level of the fresh ground waters was 180 cm below the surface (rising to 110 cm with irrigation) did well: of 24 gray anise and Mal't bagaebski 22 were healthy. Owing to the periodic rise of the ground waters into the root zone, however, the skeletal part of the root system, which developed strongly to a depth of 60-70 cm in the normally moistened horizons, weakened in the underlying wet horizons. In general, the roots failed to develop strongly in wet sandy loam (106-150 cm). Below 130 cm, all the overgrown rootlets were dead.

Different varieties of apple trees and other tree species flourish in varying degrees in

Table 5

Density of root system of 18 year old apple trees in different soils (number of roots cut per square decimeter of profile wall at a distance of 70 cm along the normal from the tree trunk)

10 cm layer	Dark clay loam, P'yanushka variety, 8/32	Slightly solonetzic coarse clay loam brown soil, Anis apple 15/7	Solon. cemented sandy loam br. soil Anis apple 19/33	10 cm layer	Dark clay loam, P'yanushka variety, 8/32	Slightly solonetzic coarse clay loam brown soil, Anis apple 15/7	Solon. cemented sandy loam br. soil Anis apple 19/33
1	1,5	0,0	0,0	11	0,3	0,5	0,0
2	5,0	1,0	0,1	12	0,4	0,4	0,1
3	5,0	1,8	0,6	13	0,1	0,6	0,1
4	3,6	1,1	0,3	14	2,0	0,4	0,1
5	2,2	0,0	0,4	15	0,7	0,3	0,2
6	1,7	0,4	0,2	16	0,8	0,1	0,8
7	1,3	0,2	0,1	17	1,4	0,4	1,1
8	0,7	0,1	0,1	18	1,9	0,4	0,2
9	1,7	0,7	0,0	19	0,9	1,8	0,0
10	0,9	0,8	0,0	20	2,0	—	0,0
				21	1,0	—	0,0

Note: Comma represents decimal point.

Table 6

Condition of apple tree varieties on slightly solonetzic brown soil (Stakhanovskiy orchard), 1953

Variety	Year of planting	No. of trees	No. of trees in percentage scale				No. of failures
			5	4	3	2+1	
Dobryy khrest'yanin	1932	20	0,5	10,0	0,0	30,0	60,0
Lithuanian pippin	Same	144	0,7	4,9	6,3	9,7	78,4
Gray Anis	» »	34	2,9	14,7	23,5	26,5	32,4
White Skrut'	» »	158	5.7	22,8	16,5	24,7	30,3
Grey Anise	» »	87	3,5	18,2	29,9	19,6	28,8
Mal't bagaevski	» »	112	25,0	37,5	10,7	12,5	14,3

Note: Comma represents decimal point.

one and the same soil (Table 6).

Of a large selection of apple varieties, the Mal't bagaevski proved the most stable. Trees of average growth of this variety in the Stakhanovskiy orchard measured 5.6 m in height, 8.3 m in crown diameter, and 73.2 cm in trunk circumference. These values indicate that the variety in question flourishes on slightly solonetzic soil. Similar data were obtained for the gray anise, although the resistance of this variety declines much more sharply than that of the Mal't bagaevski under unfavorable soil conditions. 90% of the Lithuanian pippins planted in slightly solonetzic soil failed.

Among the stone fruits, we studied the growth of cherry trees in brown soils.

Comparing the evaluation data for apple and cherry (Table 3), we find that the latter is less demanding in regard to soil conditions. In solonetzic brown soil, for example, where the applies failed (57.3% mortality), Rastun'ya cherries flourished much better (western part of stand No. 22), despite the heavy compaction of certain horizons. Of a total of 147 trees, 73.4% of them were healthy (medium-sized and weak trees predominating).

In slightly solonetzic brown soils (central part of stand No. 22, profile 101) the cherry trees flourished; the evaluation data show 93% of them as healthy. Tree measurements performed on sample plots corroborate these values.

From the values shown in Table 7 it follows that trees in solonetzic soil do not grow as well as those in slightly solonetzic soil. Not only do they grow less strongly, but in addition the foliation is poorer, the leaves being smaller and lighter. The growth history of skeletal branches in healthy trees on these soils reflects this pattern.

The root system develops more thickly in slightly solonetzic soil. In the solonetzic soil it is more superficial (20-50 cm). A cherry orchard on slightly solonetzic soil in stand 21 on the Mikoyan Sovkhoz is also in excellent condition.

Conclusions

1. Different species and varieties of fruit trees develop unequally on brown soils.

2. The pear is most resistant and tolerates a high degree of salinization of the soils and

Table 7

Mean sizes of typical cherry trees in different soils

Soil	Year of planting	Row	Height of trees, m	Diameter of crown, m	Circumference of trunk, cm
Brown solonetzic	1949	51	2,7	2,5	19,1
Brown weakly alkaline	Same	25	3,2	2,7	20,6
Same	"	10	3,9	3,1	29,0

Note: Comma represents decimal point.

Table 8

Solonetzic soil

	Years						Mean total for 1948-1953
	1948	1949	1950	1951	1952	1953	
Rastun'ya cherry, 51/8							
Primary branch	41	40	36	46	27+pruned	56	239
Secondary branch	42	48	20+pruned	30	57	58	
Rastun'ya cherry, 25/12							
Primary branch	38	19+pruned	21+pruned	70	74	43	272
Secondary branch	33	47	19	71	61	47	
Rastun'ya cherry, 10/7							
Primary branch	32+32	8+24	47	71	36	64	306
Secondary branch	63	36	39	30	55	75	

puts out roots to the moist layers, which is of great importance in arid climatic conditions.

3. Cherries are also highly resistant. They grow well on a properly irrigated slightly solonetzic brown soil.

4. There is large-scale failure of young apples on solonetzic and solonchakic brown soils. Their life is too short on slightly solonetzic soil, but the more resistant varieties (Mal't bagaevski and gray anise) can be maintained for a long period if properly tended.

5. On sectors with slightly solonetzic brown soils and a small percentage of solonetzic soils, new orchards should be planned so that the main areas are occupied by cherries of various maturing varieties and by pears. Apples should not be planted on these soils, or as few as possible should be planted. Dark soils are more suitable for apples as long as they are not waterlogged by thaw waters for a long period.

6. Between rows deep plowing should be carried out in all established orchards and the soil should receive gypsum treated with humus and superphosphates. After this treatment the orchards should be irrigated frequently and at small amounts (500 m^3/ha). The non-cultivated soil between rows should be treated in the same way every 2-3 years.

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MOISTURE-ACCUMULATION IN A FALLOW FIELD IN THE SOUTHWESTERN FOREST-STEPPE OF THE UKRAINIAN SSR

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Besides cleaning the soil from weeds and converting inaccessible forms of plant nutrient elements into easily available forms, a fallow field also accumulates water, and this is the main purpose of clean fallows.

In field crop rotations in the southwestern part of the forest-steppe of the Right Bank Ukraine, clean fallow fields occupy from 6% to 10% of the area. A considerable part of the winter wheat crop is distributed over the clean fallow fields. A winter crop on clean fallow is considered to be the best crop prior to sugar beet. An explanation of the role of clean fallow in water accumulation and in the water regime of the soil in the cycle of a crop rotation is therefore of great importance.

Annual precipitation in the southwestern part of the Right Bank forest-steppe is about 490 mm. It is smallest in January, February, and March (22-26 mm). From March onwards, average monthly precipitation increases, reaching its maximum in June and July (65-69 mm). Subsequently it gradually becomes less towards the end of the year until it is down to 30 mm. Nevertheless there are considerable annual and monthly fluctuations in the amount of precipitation. For instance, in 1946, the Khristianovka meteorological station recorded a total of 324.5 mm and in 1948, 707 mm. In August 1948 the amount of precipitation was 286.5 mm and in July 1947, it was 123 mm, but in April and in two ten-day periods, in May 1946, it was no more than 6.5 mm.

Uneven precipitation, when the air temperature is high and relative humidity is low, often causes prolonged periods of drought and reduced harvests. In such conditions it becomes of enormous importance that reliable sources of moisture should be established and that these should be utilized in the most economic way.

We studied the dynamics of soil moisture in the fallow field of a ten-field crop rotation: 1 — mixed grasses; 2 — mixed grasses; 3 — winter wheat; 4 — sugar beet; 5 — peas; 6 — winter wheat; 7 — black fallow; 8 — winter wheat; 9 — sugar beet; and 10 — barley undersown with perennial grasses. The soil of the experiment region was podzolized chernozem. Ground-water table was at 5-6 m.

Observations over five years (1953-1957) showed that when winter wheat followed peas, the residual moisture content in a 1-1/2 m soil layer amounted to 54.8 mm. In years when precipitation was plentiful the residual moisture content before the harvesting of the winter-crop preceding the fallow reached 90-144 mm (1953-1954). In years when the first half of the summer was less rainy it went down to 23 mm (1952, 1956).

In the period from harvesting winter wheat until the freezing of the soil in the autumn, the southwestern part of the Ukrainian forest-steppe had an average precipitation of 159 mm, only 48% of which was retained in the soil.

With the reduction in the residual moisture content after the harvesting of the winter crop preceding the fallow, and with the increase in the amount of precipitation, the utilization of the latter improved. In 1952, after the harvesting of the winter crop, 23.7 mm of available moisture remained in the 1-1/2 m soil layer, i. e., 34.7% of the 142.2 mm precipitation was retained in the soil; in 1956, when the residual moisture content was the same as in 1952, 63.9% of the precipitation of 229.4 mm was preserved. In 1954, when the residual moisture content reached 90.5 mm and the quantity of precipitation 122.2 mm, the utilization was 29.7%. Finally, in 1953, when there was 144.2 mm residual moisture content, the precipitation (40.9 mm) was not only not retained but there was actually a loss of 14.0% of the moisture which had remained in the soil after the harvesting of the winter crop preceding the fallow.

In the end, by the time of the autumn freezing, there was slightly more than 130 mm of available moisture in the 1-1/2 m soil layer of the fallow field, with fluctuation over the years from 73.1 to 169.7 mm.

Of the 134.4 mm winter precipitation the black fallow retained 50.9% and the total content of available moisture in the 1-1/2 m layer amounted to 200.2 mm by the spring, that is, the wetting of the soil amounted almost to the maximum field moisture capacity. In individual years (1953, 1954, 1955), the utilization of winter precipitation amounted to 68%-92%, which were record amounts. In years when the autumn moisture contents in the soil amounted to 160-170 mm, the absorption of winter precipitation in the root layer decreased sharply (1956, 1957). In addition to the size of the autumn moisture content, there are various factors which play an important part, such as the nature of the freezing of the soil (when it begins, its length and how deep it goes) and the weather conditions in the spring.

However, whereas precipitation in a fallow field may be well retained in the winter (or, more exactly, the spring), it will be poorly utilized in the summer in a fallowing year. Of 289 mm precipitation which fell during the period from the spring thaw to the sowing of the winter crop, not one millimeter was retained in the 1-1/2 m soil layer in the fallow field. Moreover, by the time of the sowing of the winter crop, 32 mm, or 11.2% of the spring moisture content, was lost. A small absorption of the summer precipitation in the fallow field was observed only when the spring moisture content in the fallow was comparatively small (1954-156 mm) and the amount of summer precipitation was quite considerable (Table 1).

Loss of moisture in a fallow field can come about in various ways. With the high air temperature and low relative humidity which accompanies precipitation in the summer months, evaporation increases both from the surface of the soil and from the deeper horizons. In years when summer precipitation was very poorly retained by the soil, the mean diurnal air temperature during the summer was 2-3°C higher than the long-term average. In 1953, when 27.4% of the spring moisture content was lost during the summer, the mean air temperature in June reached 19.8°C (normal mean temperature 17.2°C), in July 21.1°C (normal mean temperature 19.0°C), in August 19.2°C (normal mean temperature 18.3°C). At a depth of 20 cm the temperature of the soil at this time reached 22-23°C. In such temperature conditions it has been proved that precipitation amounts of from 5-10 mm, which in colder periods of the year can be used, cannot be utilized in the summer months.

Loss of moisture becomes greater with the increased moisture in the soil. The facts presented by Bityukov and his colleagues (2) show that the more moist the soil is the more it gives off moisture. Fabrikant (11) and Poznyshev (8) have reached the same conclusions. Parkhomenko (7) shows that when the soil moisture reaches approximately 66% of field moisture capacity, evaporation from the soil surface becomes similar to evaporation from a water surface. Burov (3) notes that in the conditions obtained in the Trans-Volga region evaporation of water from a surface of fallow soil is 1-1/2 to 2 times greater than from a soil surface with

Table 1

Accumulation of precipitation on black fallow

Indices	Under fallow in					Average
	1953	1954	1955	1956	1957	
Available moisture in a 1-1/2 m soil layer after harvest of crop preceding fallow, mm	23,7	144,2	90,5	—7,9	23,3	54,8
Available moisture in a 1-1/2 m soil layer in autumn after harvest of crop preceding fallow, mm	73,1	124,0	126,9	164,5	169,7	131,6
Precipitation during period from harvest of previous crop until autumn freezing, mm	142,2	40,9	122,2	260,3	229,4	159,0
Precipitation retained during the period, %	34,7	—14,0	29,7	66,1	63,9	48,1
Available moisture in a 1-1/2 m soil layer in spring of fallow year, mm	229,0	156,0	224,7	168,4	222,9	200,2
Winter precipitation, mm	219,1	34,5	111,2	126,9	180,3	134,4
Winter precipitation retained, %	68.2	92,5	88,0	3,1	29,5	50,9
Available moisture in a 1-1/2 m soil layer before sowing winter wheat on fallow, mm	166,4	194,9	144.0	171,6	162,8	167,9
Precipitation from spring to sowing of winter wheat in fallow year, mm	313,1	294,2	349,6	257,6	232,7	289,4
Precipitation retained during period from spring to sowing of winter wheat, or amount of moisture lost, %	—27,4	13,4	—36,0	1,2	—27,0	—11,2

Note: Comma represents decimal point.

vegetation. An increase in evaporation is also caused by the periodicity and frequency of soil wetting.

In addition to evaporation and surface runoff which would appear to be the principal and most dangerous means by which there is a loss of moisture from a fallow field, a less dangerous cause of loss is when there is outflow or percolation beyond the 1-1/2 m limit of the soil layer. But, as can be deduced from the facts given by Kolpakov (5), an increase in the computed layer of soil from 1.5 to 2 m substantially increases the coefficient of utilization of precipitation.

It is not only in the conditions existing at the Cherkassky experiment station that considerable moisture losses have been observed during the summer in fallow fields. An analysis of the data published by the Belotserkovsky experiment station (1) show that on the average during the five years, 1951-1955, in the period from the spring thaw to the sowing of winter wheat, only 4.3 mm of available moisture accumulated in the 1-1/2 m soil layer of fallowing field; this constitutes about 2% and is hardly of practical significance.

In only two of the years mentioned previously (1954 and 1955), when the spring moisture contents in the fallow were comparatively small, was moisture accumulation observed; in the other years (1951, 1952, and 1953) the moisture losses in the 1-1/2 m soil layer during the summer period amounted to 5.7%-10.8% (Table 2).

Here the black fallow collected 136.7 mm of available moisture between the harvesting of the previous crop and the spring thaw. In this period utilization of precipitation amounted to 50.4%.

The report issued for the Drabovsky experimental field at the Cherkassky experiment station (10) shows that 63.7% of the autumn-winter precipitation was retained by the fallow field. In the left Bank Ukraine during this period the 1-1/2 m soil layer collected 81.1 mm of available moisture and its spring moisture content exceeded 177 mm (average for the years 1951-1957). The spring-summer precipitation was as poorly retained here in a fallow field as in the Right Bank Ukraine and the average loss of spring moisture content over the seven years (1951-1957) in a fallow field amounted to 15.8%. In individual years (1951, 1953, 1955) the loss amounted to 26.7% and more, and it was only during the summer of 1956 in the fallow year up to the sowing of the winter crop that the available moisture

Table 2

Accumulation of available moisture in a fallow field in a fallow year. Data obtained at the Belotserkovsky experiment station

Period	Available moisture in a 1-1/2 m soil layer in the years:					
	1951	1952	1953	1954	1955	Average
Spring thaw	247,6	272,5	270,7	117,3	210,6	223,7
Sowing of winter wheat	221,0	257,0	243,0	187,0	233,0	228,0
Accumulation or loss of moisture, mm	—26,6	—15,5	—27,7	+69,7	+22,4	+4,3
The same, %	—10,8	—5,7	—10,2	+59,4	+10,6	+1,9

Note: Comma represents decimal point.

Table 3

Moisture accumulation by a fallow field of crop rotation during fallow year in the western part of the left bank forest-steppe of the Ukrainian SSR (Data supplied by the Drabovsky experiment station)

Period	Available moisture in a 1-1/2 m soil layer in the years, mm							
	1951	1952	1953	1954	1955	1956	1957	Average
Spring thaw	187,5	198,6	259,7	100,4	203,9	100,1	190,4	177,2
Sowing of winter wheat	132,9	171,5	182,2	82,1	149,4	151,6	175,1	149,2
Accumulation or loss of moisture, m	—54,6	—27,1	—77,5	—18,3	—54,5	+51,5	—15,3	—28,0
Ditto, %	—29,1	—13,7	—29,9	—18,2	—26,7	+51,5	—8,0	—15,8

Note: Comma represents decimal point.

content went up 1-1/2 times in the 1-1/2 m soil layer (Table 3).

These facts show that a fallow field poorly utilized the summer precipitation, and in many cases even lost part of the moisture which had accumulated in the autumn-winter period. An analysis of the dynamics of the total content of moisture does not offer sufficient basis for an explanation of the peculiar nature of the accumulation and disposal of moisture throughout the soil profile.

As was pointed out earlier, after the harvesting of the crop preceding the black fallow (winter wheat), a comparatively small residual available moisture — about 50 mm — remains in the 1-1/2 m soil layer. The upper meter of soil is particularly poor in moisture. It is mainly towards autumn that the available moisture content is replenished in this layer and it is only towards spring in the fallow year that a renewal of the available moisture content is observed throughout the 1-1/2 m soil profile. In the summer period, up to the sowing of the winter crop, losses of moisture in a fallow field are observed throughout the soil profile, but the upper third loses almost as much as the two lower thirds. By the time of the autumn freeze (after the sowing of winter wheat), the available moisture content begins to be replenished. When this occurs, a very even distribution of available moisture is observed throughout the soil profile (Table 4).

Table 4

Distribution of available moisture in a 1-1/2 m soil layer in a fallow field
(Cherkassky experiment station)

Depth, cm	Quantity of available moisture in mm for observation periods				
	After harvest of crop preceding fallow	Autumn after harvest of preceding crop	Spring of fallow year	Time of winter wheat sowing	Autumn before freezing
	1952—1957		1953—1957		
0—50	9,9	54,4	75,5	57,7	61,1
51—100	12,6	31,6	66,0	57,4	61,0
101—150	25,3	31,6	60,3	52,4	65,9
0—150	47,8	117.8	201,5	167,5	188,0

Note: Comma represents decimal point.

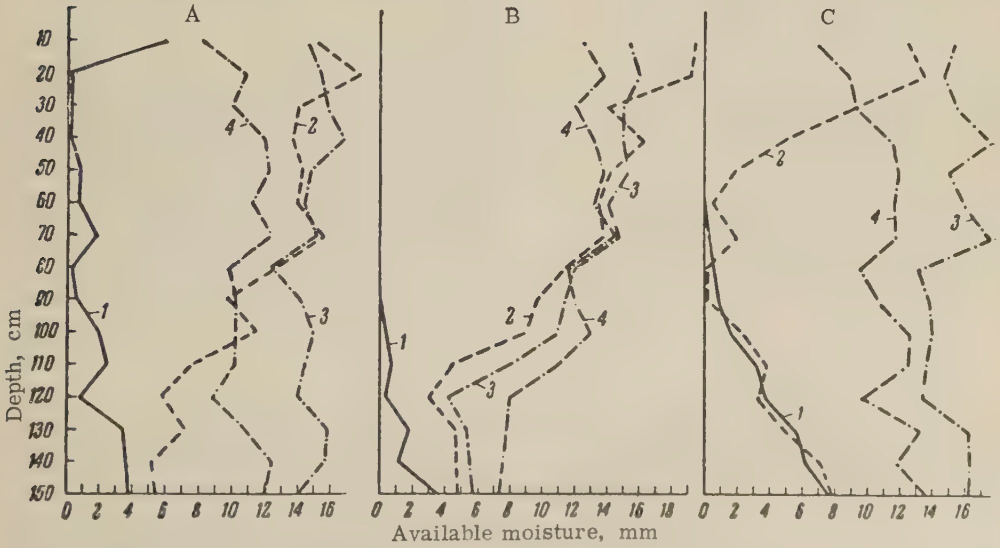

Fig. 1. - Dynamics of available moisture in a 1-1/2 m soil layer in a fallow field. A - 1956-1957. B - 1955-1956. C - 1952-1953. 1. harvesting of the crop preceding black fallow; 2 - autumn freezing in the year when the crop preceding black fallow is harvested; 3 - in spring of the fallow year; 4 - before sowing of winter wheat.

When winter wheat precedes fallow, a fairly long period of time (3-3-1/2 months) elapses following its harvesting until the soil freezes. In years when there is plentiful precipitation in the second half of the summer (1956), the replenishment of the moisture in the autumn affects almost the entire 1-1/2 m soil layer and in the upper meter the moisture is completely restored. By the spring in the fallowing year it has been observed that the moisture content has been fully replaced throughout the profile, including the bottom third, but by the time of the sowing of the winter crop the quantity of moisture throughout the profile has begun to decrease (Fig. 1, A).

Where precipitation is small in the autumn-winter period after the harvesting of the preceding crop and in the summer in the fallow year, the available moisture content in the bottom third of the profile will not even be restored by the time the winter crop is sown. A very slight movement of moisture is observed from the upper half of the profile to the lower (Fig. 1, B).

When the 1-1/2 m soil layer is completely dry and there is only a small amount of precipitation after the harvesting of the preceding crop to the autumn freezing, the available moisture content is restored within the plowing layer and its full replenishment throughout the profile is not observed till the spring in the fallow year (if winter precipitation is adequate). By the time the winter crop is sown, the quantity of moisture throughout the profile becomes smaller, which is apparently connected both with evaporation and with the migration of the moisture to deeper horizons (Fig. 1, C).

When fallow is preceded by a crop which is harvested later than winter wheat (sugar beet, sunflower), the full replenishment of the moisture content throughout the profile is observed mostly by the time the winter crop is sown.

The facts collected over many years by the Belotserkovsky experiment station show that the replenishment and distribution of available moisture in the soil profile have the same character as at Cherkassky (Table 5).

At the Drabovsky experiment field the available moisture content in the soil profile is replenished in a different way. Owing to the poor physical properties of the soil, the moisture from precipitation does not easily penetrate to the lower third of the 1-1/2 m soil layer; this causes the moisture contents to be unstable and subject to quick losses. There is no essential replenishment in the bottom 1-1/2 m until towards the autumn freezing, after the sowing of winter wheat on the fallow (Table 6).

As has been pointed out previously, by the time the winter wheat is sown on the black fallow, the average accumulation of available moisture over the seven years has been up to 200 mm. During the period from the sowing of the winter crop to the autumn freezing, 14.6% of the available moisture in the 1-1/2 m soil layer before the sowing of the winter crop has disposed (exclusive of the precipitation of 51 mm during this period). In years when precipitation is slight, the autumn consumption of moisture by a fallow winter crop has increased from 14.6% (29 mm) to 30%-35% (58.4 mm). Increase in the available moisture contents up to the time of autumn freezing has been observed only in cases where more than 100 mm precipitation has fallen after the sowing of the winter crop.

The facts observed over many years show that a fallow winter retains about 45% of the 118.9 mm of precipitation, as a result of which the quantity of available moisture in the 1-1/2 m soil layer is replenished and reaches 219.7 mm by the spring thaw. The drier the soil and the greater the precipitation, the higher is the utilization.

A comparison of the water regime in the 1-1/2 m soil layer occupied by the principal previous crops of winter wheat (black fallow, perennial grasses, peas) shows that the maximum difference in soil moisture contents with these crops is observed at the time when they are harvested. By the time of sowing the winter crop, however, this difference is reduced as a result of the better absorption of precipitation by the drier soil. An important role in this is played by the improvement in the permeability of the soil after the perennial grasses. In the seven years (1949-1956) the average available moisture content on the fallow before sowing the winter crop was 185.7 mm, and after the perennial grasses, 151.3 mm. In the time from sowing to the onset of winter, a winter crop on the black fallow consumes the moisture more quickly since in the development of its tops it usually outdistances a winter crop following grasses. As a result of this the moisture content under winter wheat on the

Table 5

Distribution of available moisture in a 1-1/2 m soil layer. (Data from the Belotserkovsky experiment station, 1951-1955)

Period	Available moisture in mm by soil layers, cm					
	0—3	31—60	61—90	91—120	121—150	0—150
Spring of fallow year	59,8	49,9	44,8	34,9	34,3	223,7
Before winter crop sowing	49,2	45,7	45,2	42,2	40,9	223,2

Note: Comma represents decimal point.

fallow and following grasses evens out, although in individual years with a dry autumn the moisture under winter wheat following grasses is substantially less.

Calculations show that for 1 cntr of the total yield of a fallow winter crop (grain with the corresponding amount of straw) 4.98 mm of water is used up, and for 1 cntr of yields of a winter crop following grasses, 4.7 mm. If we allow for the water lost by the fallow field up to sowing the winter crop, its utilization sharply increases and constitutes, respectively, 9.08 and 6.45 mm.

Table 6

Accumulation and distribution of available moisture throughout the soil profile in a fallow field in the left bank Ukraine. (Data from the Drabovsky experiment field, 1951-1957)

Depth, cm	Available moisture in mm by periods			
	Autumn of year when preceding crop is harvested	Spring of fallow year	Before sowing winter crop	Autumn in year of sowing winter crop
0—50	56,3	96,7	65,5	71,5
51—100	42,4	60,8	56,2	62,5
101—150	23,9	19,8	27,5	41,8
0—150	122,6	177,3	149,2	175,8

Note: Comma represents decimal point.

Table 7

Influence of crops occupying the fallow field on the water regime of soil under winter wheat

Indices	Year of calculating yields and crops preceding winter wheat			
	1949—1956		1954—1958	
	Black fallow	Perennial grasses	Black fallow	Peas
Available moisture in a 1-1/2 m soil layer after harvest of preceding crop, mm	97,4	120,6	54,6	77,2
Same, in a 1-1/2 m soil layer at time of winter wheat sowing, mm	185,7	151,3	167,9	87,3
Precipitation during the period, mm	498,1	190,7	529,7	115,0
Available moisture in a 1-1/2 m soil layer in autumn in year of winter crop sowing, mm	168,2	160,5	187,8	122,0
Precipitation during period from winter crop sowing to autumn freezing, mm	61,8	57,1	83,6	80,0
Utilization of precipitation or moist. loss, %	—9,4	16,2	23,9	43,4
Available moisture in a 1-1/2 m soil layer in spring of year of winter crop harvest, mm	210,4	178,1	211,1	157,2
Precipitation in the winter, mm	91,1	92,8	123,5	129,4
Available moisture in a 1-1/2 m soil layer at time of winter crop harvest, mm	80,0	76,7	43,5	28,4
Precipitation in summer period, mm	215,5	202,2	183,6	177,3
Moisture expenditure during growing period, mm	474,1	426,7	515,1	445,6
Moisture expenditure during period from harvest of preceding crop to winter crop harvest, mm	883,9	586,7	931,5	550,5
Consumption per cntr of harvest: during growing period, mm	4,98	4,7	5,6	5,55
From harvest of preceding crop to winter crop harvest, mm	9,08	6,45	10,3	6,86
Total yields, cntr/ha, grain + straw	97.3	90,9	91,8	80,3

Note: Comma represents decimal point.

Table 8

Influence of crops occupying fallow on the water regime of soil under sugar beet

Period	Available moisture in a 1-1/2 m soil layer in the crop rotation, mm		
	Black fallow - winter wheat - sugar beet	Perennial grasses - winter wheat - sugar beet	Peas - winter wheat - autum plowland
In autumn, after sowing winter wheat, 1953-1955	183,3	128,2	121,4
In spring, after the thaw, 1954-1956	203,7	143,9	132,4
Time of winter crop harvest, 1954-1956	55,4	59,8	35,3
In autumn, after plowing	160,4	141,8	153,7
In spring in the year of beet sowing, 1955-1957	190,7	175,6	205,3

Note: Comma represents decimal point.

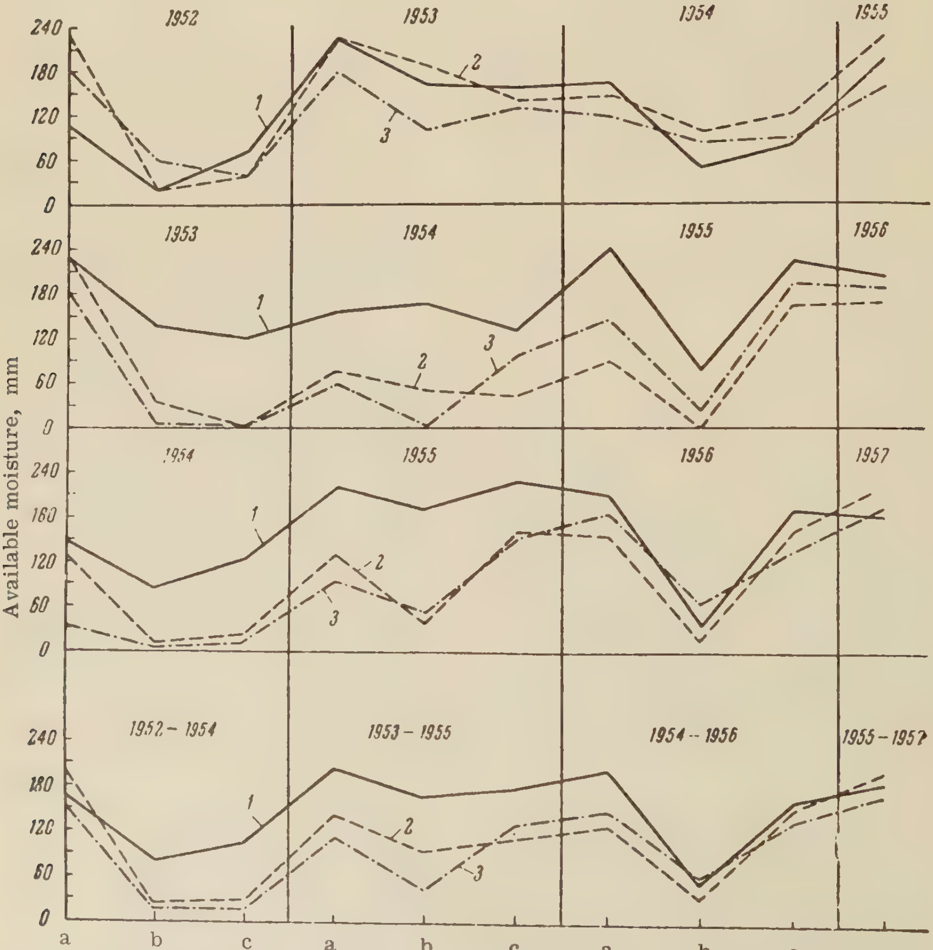

Fig. 2. - Dynamics of available moisture in a 1-1/2 m soil layer in various crop rotations. 1 - winter crop - fallow - winter crop - beets (autumn plowing); 2 - beets - peas - winter crop - fallow (autumn plowing); 3 - grasses - grasses - winter crop - beets (autumn plowing); a - spring; b - harvest; c - autumn.

A comparison of the water regime of black fallow soils and pea fallows (1954-1958) shows that a pea fallow is even more inferior to a black fallow in the available moisture content in the 1-1/2 m soil layer at the time of the sowing of the winter crop than is a perennial grass sod. The average amount of available moisture in the years 1954-1958 before the winter crop was 167.9 mm on the fallow and 87.3 mm after peas. By autumn this difference had been sharply reduced (owing to the better utilization of precipitation after the pea harvest) and the moisture content grew respectively to 187.8 and 122.0. In spring the available moisture content in this soil layer under winter wheat on the black fallow reached 211.1 mm, and following peas, 157.2 mm. The consumption of moisture per cntr of produce, including the moisture lost in the fallowing period, amounted respectively to 10.3 mm and 6.9 mm and, excluding the moisture lost in the fallowing time, to 5.6 mm and 5.5 mm (Table 7).

The average harvest of winter wheat following

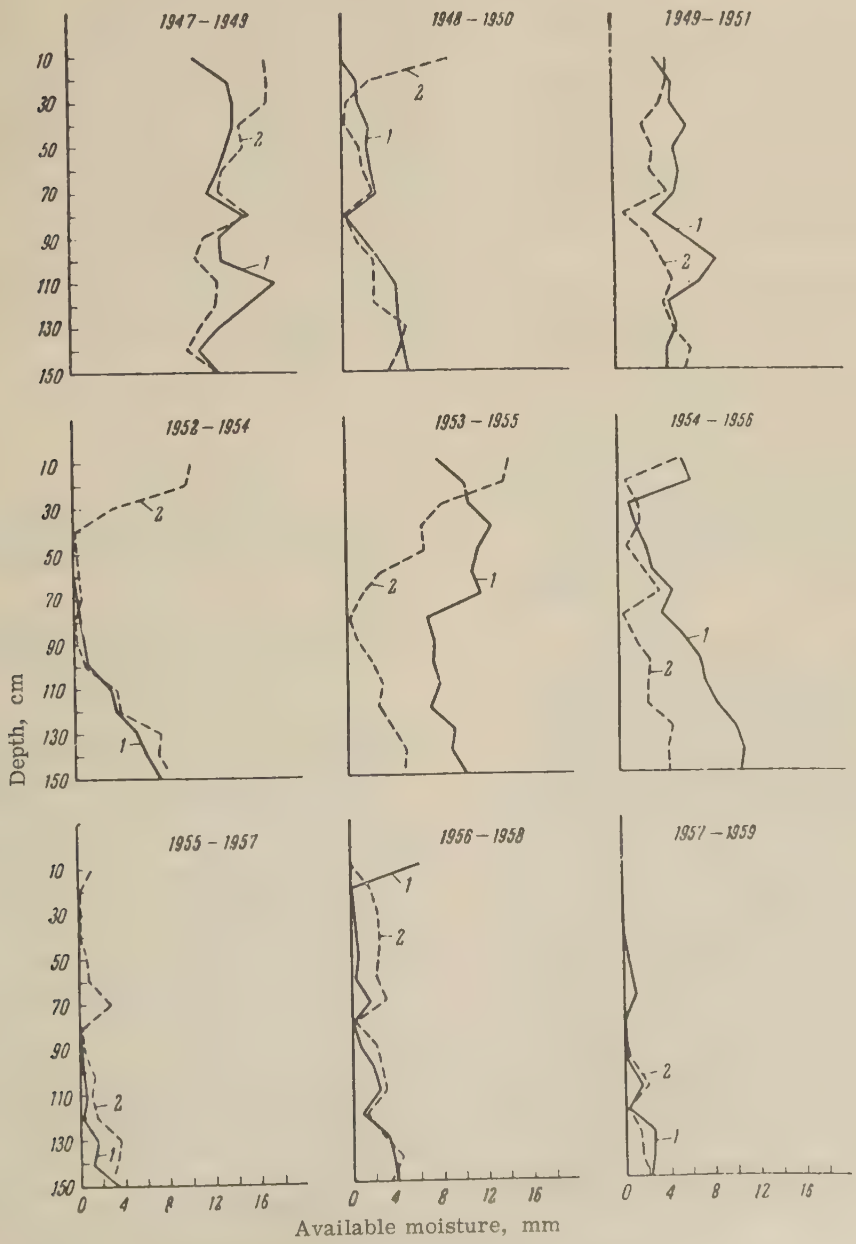

Fig. 3. - Distribution of residual available moisture contents in a 1-1/2 m soil layer. 1 - after harvesting the crop preceding black fallow; 2 - after harvesting winter wheat following black fallow.

the three previous crops over seven years (1952-1958) was: following black fallow, 32.6 cntr/ha; following perennial grasses, 30.4; following peas, 29.8 cntr/ha. The hay yield of perennial grasses amounted in one yield to more than 34 cntr/ha, and the pea harvest, to 27 cntr/ha. The comparatively slight superiority of the fallow winter crop is due to the fact that a winter crop following fallow is usually greatly lodged. Consequently, on the black fallow a considerable part of the moisture is used unproductively.

After harvesting the winter wheat following clean fallow, perennial grasses, and peas, there is an almost identical amount of available moisture in the 1-1/2 m soil layer; the difference between the remaining amounts after the harvest of the winter crop with these previous crops does not exceed 20-25 mm. By autumn the moisture contents even out, and by the spring, in a year of beet sowing, in fallow occupied by peas — fallow — winter crop, the moisture is even somewhat larger than in the black fallow — winter crop (Table 8).

The data graphically presented in Figure 2 show that it was only in 1956 in the fallow — winter crop — beet that the available moisture contents before the sowing of beet were considerably higher than in the other portions of rotation. The moisture deficit in the grasses — grasses — winter crop — beets, and beets — peas — winter crop — autumn plowland was caused on the one hand by severe drying of the soil by grasses and beets, and on the other by poor replenishment with precipitation which was also very slight in the second half of the summer in the year in which grasses and beets were harvested: in 1952 there was 307.5 mm, in 1954 it was 231.3 mm and in 1953 only 82.5 mm.

An analysis of the distribution of the residual moisture contents in the soil profile shows that in the lower horizons, where, it would seem, the influence of the fallow ought to be particularly noticeably, the residual moisture contents after the harvest of the winter crop were the same as before fallow. Some increase in moisture contents in 1954, 1957, and 1958 was caused by the moistening of the upper horizons by precipitation (Fig. 3).

The total moisture content to remain after the harvest of the fallow winter crop was not more than the quantity which was in the soil before the beginning of fallow. On the average, over the seven years, the residual moisture contents before fallow and after the harvesting of the fallow winter crop were respectively 56.6 mm and 46.4 mm. Only when there is abundant precipitation in years when a fallow winter crop is harvested will the residual moisture contents be more than those before fallowing. The available moisture contents (in millimeters) before fallow and at the time of harvesting the fallow winter crop in the crop rotation fields amounted respectively (over the years) as follows:

Field	VII	1948-1950	42.4 mm	44.8 mm
"	VI	1949-1951	80.3 "	62.6 "
"	V	1952-1954	23.7 "	50.9 "
"	IV	1953-1955	144.2 "	76.9 "
"	III	1954-1956	90.5 "	38.4 "
"	II	1955-1957	7.9 "	19.0 "
"	I	1956-1958	23.3 "	32.5 "

Consequently, in the conditions of the Cherkassky experiment station, clean fallow does not ensure the accumulation of moisture, not only over the whole crop rotation but even for the second crop, and its effect is limited by the first crop (winter wheat). For fuller utilization of moisture, therefore, it is essential to sow a crop in the fallow field. The influence of crops occupying the fallow on the water regime of the soil, and the method of selecting the best of them, are outside the sphere of this paper. It is only necessary to point out that the best of them will be those which leave the field free early and do not cause any perceptible reduction in the winter wheat harvest. It follows that one should recognize that the most reliable crop on fallow is the vetch-rye mixture, and the most valuable, peas. Although the first can be sown almost everywhere, the second can only be sown in districts where the harvest reaches 25-30 cntr/ha and the yield of winter wheat obtained is high.

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EFFECT OF DEEP CULTIVATION ON THE COMPACTION AND BULK DENSITY OF SANDY SOILS

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It is common in agricultural practice that the principal way of preparing the soil is cultivation, which reduces the soil's resistance to the development of crop root systems, makes for the accumulation of soil moisture, and gives better aeration and weed control. It is only recently, however, that deep cultivation of the soil and subsoil has come into use in connection with the afforestation of sandy soils. There had been failures in the use of agricultural technical measures in connection with the afforestation of the Lower Dnieper sands, owing to mainly, the use of methods inappropriate to local conditions (small furrows without cultivation of the bottom or continuous working of the soil to a depth of 18-20 cm) (2). Nowadays, on the suggestion of the Lower Dnieper Scientific Research Station for Sand Afforestation and the Ukrainian Institute of Forestry and Melioration, deep mechanized cultivation of the soil and subsoil is being used on level and level to rolling sands in the Lower Dnieper forestries, and is proving successful. The preliminary mechanized cultivation is performed in the fall preceding plantation, with a converted PKB-56 plow. The soil is broken down in strips, to a depth of 60-70 cm, the distance between the strips being 2-1/2-3 m. A converted LBD-45 disk harrow is used for levelling the surface of the cultivated strips, filling up the cavities formed in the soil and removing herbaceous vegetation (1). With deep cultivation the root systems of pines develop quickly and, penetrating deep into the soil, penetrate the dry top layers and acquire resistance during periods of drought.

Our research data show that deep cultivation greatly affects the compaction and bulk density of sands. In sandy soils, of course, compaction is not only a most important factor in determining the resistance of the soil during plowing and in establishing the right traction power but also affects the development and structural study of the root systems of the young trees. It is often found that pine roots make extensive use of the roots left over from preceding vegetation in deepening their own root system. This is because the natural constitution of the soil in sands makes it difficult for the root systems to penetrate the deeper layers of the soil during the early years of the crop's life, owing to high mechanical resistance. Despite the widespread notion that sands are friable, they act as a strong barrier against the penetration of roots into the deeper layers.

In order to find the effects of deep cultivation of the soil and subsoil on the compaction of sands and its variation after cultivation we determined the compaction of sands in June 1960, in a number of plots where the soil and subsoil had been cultivated at different times and also on unworked sands. The depth of cultivation was 60 cm. Compaction was determined with a Revyakin penetrometer. The measurements were replicated five times at intervals of 10 cm in a 100 cm layer. The soil of the plot concerned was an incompletely developed sandy chernozem with a 10 cm humus horizon. The ground waters were 3 m below the surface.

The results are shown in Figure 1. Down to a depth of 60 cm a considerable difference in compaction is observed between the cultivated and the non-cultivated layers. If we take the compaction at a depth of 40 cm in the non-cultivated sands as 100%, the compaction in the plots where the soil was loosened in 1956, 1957, 1958, and 1959 to the same depth is 30%, 27.9%, 16.3%, and 13.7% respectively. This means that one year after the soil was loosened the compaction of the sands in the cultivated layers was reduced to 1/7 as compared with the non-cultivated layers. With time the sands again compact. Four years after cultivation the compaction of the cultivated layer at a depth of 40 cm is 6.7 kg/cm² against 19.0 kg/cm² in the non-cultivated sands. Investigations will have to be continued in order to establish how many years it takes for a loosened layer to revert to the same degree of compaction as natural sand.

Deep cultivation of the soil and subsoil, then, by creating good aeration conditions, makes for rapid and deep root penetration on the part of young crops.

As we know, the bulk and particle density of sands depends on their mineralogical composition. When this is constant the bulk density is closely associated with porosity and moisture. Deep cultivation of the soil and subsoil greatly affects the compaction of the sands which, in turn, affects the bulk density. Bulk density was studied on the same plots as

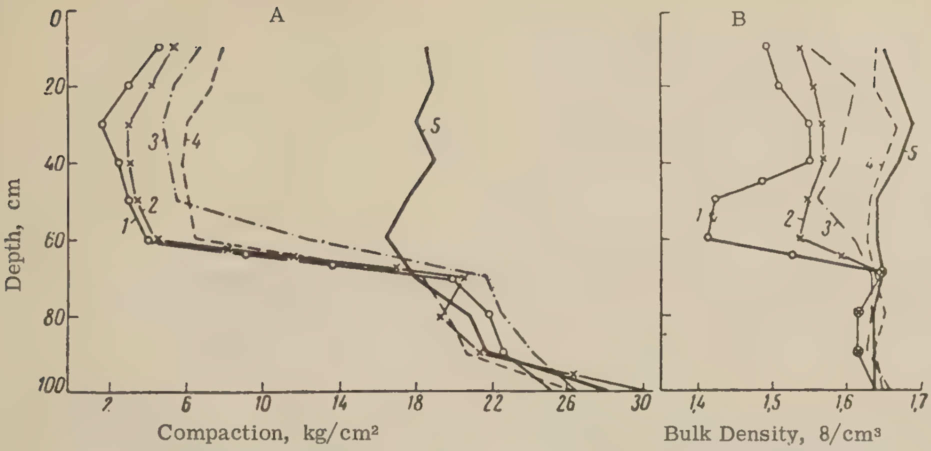

Fig. 1. - Compaction (A), and bulk density (B) of sands as a function of time lapse after cultivation. 1 - 1959; 2 - 1958; 3 - 1957; 4 - 1956; 5 - untreated soil.

compaction. Samples were taken with a tube, replicated three times at intervals of 10 cm to a depth of 100 cm.

Figure 1B shows the results obtained. Bulk density in the cultivated horizons was considerably below that in the non-cultivated horizons. The value depended on when the soil had been loosened and was in direct proportion to the lapse of time. Four years after cultivation the bulk density was still lower than in the non-cultivated sand.

The results show that the pattern of variation in bulk density as a function of the lapse of time after cultivation coincides with the variation in compaction.

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RELATION BETWEEN SOIL MOISTURE AND COTTON EXUDATION

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Numerous investigations have shown that yields of irrigated crops are highest when soil moisture in the root (calculation) layer is maintained at not less than 65%-70% of field moisture capacity (FC), (1, 2, 3, 6, 7). If soil moisture is allowed to fall lower, the plant growth is usually depressed and yields decrease sharply. Rode (6) uses the term "critical moisture" or "moisture of retarding plant growth to mean the level of soil moisture at which plant growth is slowed down; Astapov and Shishkov use the expression "moisture of depressing plant growth" (2). Rode, discussing the original research of Litvinov (5 and elsewhere), aimed at establishing a basis for this very important constant, draws attention to the close connection between critical moisture or moisture of retarding plant growth on the one hand and the rate of plant growth and cessation of exudation from the cut on the one hand and the rate of plant growth and cessation of exudation from the cut stem, on the other. The investigations of Litvinov and Kolotova, however, were not continued. The quantitative relationship between the most important water-physical constants of the soil and the amount of exudation indicating that soil moisture is physiologically available to the plants has remained unknown.

In view of the great importance of exudation phenomena for establishing the critical degree of soil moisture for plants under irrigated cultivation we made a series of investigations with the aim of establishing the quantitative relationship between soil moisture and the direction of the cotton exudation and yield. Results showed that positive exudation was a sign of a favorable water regime, whereas negative exudation indicated a water deficit (9, 10).

In this communication we give the results of investigating cotton exudation in regulation to soil moisture under field conditions and evaluate this relationship in terms of the availability of soil moisture to plants and the critical level of soil moisture.

The investigations were made on experimental plantations at the Ukraine Institute of Scientific Research on Irrigation Husbandry (Kherson) in 1954-1956. The degree of exudation was determined by the method previously used during the budding and flowering periods, both with and without irrigation. In each case four or five typical plants were selected from points which differed as regards soil wetting; soil moisture at these points was determined, too.

The top portion of the plants was cut at different times of the day at a height of four or five cm above the soil surface. Graduated glass tubes, half filled with water, were attached to the stems of the cut plants. The direction of exudation was determined from the position of the meniscus in the tube.

In 1954 the soil moisture was determined only at a depth of 30 cm, since we had established that at this depth the moisture of the soil in question, whether under cotton or other crops, was in most cases equal or approximately equal to the mean moisture of the theoretical layer (11). In 1955 and 1956 the soil moisture was again determined at every 10 cm. The measurements were made three or four times at each point.

The soils in the plots concerned are slightly solonetzic chestnut silty coarse clay loams. Field moisture capacity in the top meter layer varied from 19%-21%, according to genetic horizon, and the wilting moisture was 7%-8%.

1954 was a year of considerable drought. Irrigation experiments were performed once or several times, up to four times. The raw cotton yield amounted to 20-22 centners per ha. The years 1955 and 1956 were comparatively cold, with abundant precipitation in the first half of summer until the flowering stage of the cotton. Irrigation was done once or twice and the yield of raw cotton was 16-18 centners per ha.

Figure 1 compares the exudation rates obtained two hours after the plants were cut in 1954. The stems were cut at 13:00-14:00 hours during the flowering and budding periods.

The comparison shows that exudation was positive when the soil moisture at a depth of 30 cm was more than 65% of field moisture capacity and that when it was less than 60% of field moisture capacity exudation was negative.

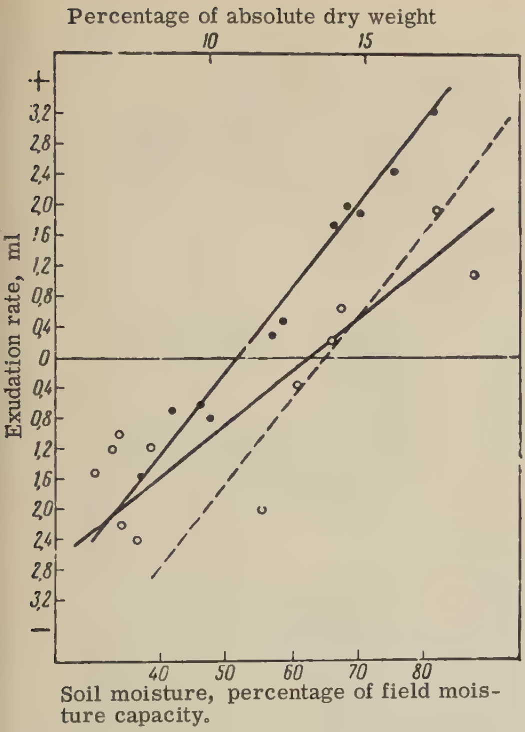

Fig. 1. - Relationship between cotton exudation and moisture of slightly solonetzic chestnut soil at a depth of 30 cm.
Open circles - exudation in plants cut at 13-14:00 hours. Black circles - exudation in plants cut at 10:30-11:00 hours (4 days after irrigation).

The change from positive to negative exudation occurred when the soil moisture was just under 65% of field moisture capacity or, in other words, at the same stage as we had observed cotton exudation to cease in similar soils at the Brilevsk Experimental station in 1952 (9). The reason why the experimental points are so scattered is that the rate of exudation depends largely on the extent of root systems. As Krasovskaya's (4) and Sus's (8) investigations show, the better the development of the root system the higher the rate of exudation. This was observed by us when we determined the exudation from cotton at different stages of the plant's development but an identical degree of soil moisture.

Figure 1 also compares the soil moisture with the simultaneous exudation from a group of plants on a plot unevenly wetted by irrigation (black circles). The soil was wetted to a depth of 40-50 cm at some points, while at others only the top 5-7 cm layer was wetted. The plants were cut between 10:30 and 11:00 o'clock the morning of August 11th, four days after irrigation, when the bolls were beginning to form. At the well-wetted points abundant secretion was observed, whereas at the points where the soil moisture was low, at a depth of 30 cm and in other parts of the root layer, exudation was negative. In this instance simultaneous determination of the exudation from equally well-developed plants revealed a more pronounced qualitative relationship between the exudation rate and the soil moisture. The scatter of the points from the straight line was negligible. The values obtained are evidently a correct reflection of the relationship between the soil moisture and cotton exudation. Nevertheless, when the soil moisture was lowered, it was found that exudation changed from positive to negative. This shift can be explained by the fact that the diurnal exudation peak occurred between 11:00 and 13:00 hours, the plants having been cut earlier, in accordance with the known phenomena of daily periodicity. When the plants were cut later, at 13:00 to 14:00 hours, the straight line on the graph shifted to the right, roughly into the position indicated by the dotted line. Comparing the position of this straight line with the series of first determinations we can readily see that the majority of the points lie very near it, except for four, owing to negative exudation, which lie to the left of the graph. The reason for this deviation is that two determinations were performed on a non-irrigated plot where the plants and, obviously, their root systems were poorly developed, and two at the end of the budding stage, in less well-developed plants. If we exclude the influence of this secondary factor on the exudation rate we can detect a very clear quantitative relationship between exudation and soil moisture.

Under field conditions the degree of soil wetting along the profile of the root layer may vary greatly. In most cases the lower parts of this layer will be more wetted than the top parts. In irrigated plots, however, the top layers of the soil are often more wetted than those below. This happens after irrigation to low standards or after rain which has wetted the top 20-30 cm of soil. Such conditions do of course exert a definite influence on the quantitative relationship between exudation and the mean moisture content of the calculation layer, as can be seen from the numerous determinations we made in 1955 and 1956.

Table 1 shows the results of the 1955 determinations, giving the rate of exudation three hours after the instruments were mounted and the calculated moisture content for the first half meter and meter layer.

Comparing the data we find confirmation for the common pattern: when the soil moisture is high plant exudation is positive and when the soil moisture is low plant exudation is negative, no matter which plot we take, and irrespective of whether irrigation has been applied or not. The maximum exudation was generally found to occur when the plants were cut at 12 or 9 o'clock, as one would expect in view of the diurnal periodicity effects in the physiological processes of the plants (12). No such distinct quantitative relationship between the cotton exudation and the soil moisture, as was found in 1952 and 1954, could be detected in this year. The change from positive to negative exudation when the plants were cut at midday occurred when field moisture capacity was between 60% and 50% — in other words, at a lower moisture. This was due to the peculiar water regime created for the plants.

Table 1

Relationship between cotton exudation and soil moisture, 1955

Determin-ation date	Stages and periods of development	Treatments	Cutting time (hr)	Exudation rate, 3 hrs. after cutting, ml	Mean soil moisture as percentage of field moist. cap. in layer, cm	
					0—50	0—100
July 23	Budding	Without irrigation	9	+0,11	55,1	61,5
			12	—0,32		
			15	—0,19		
Aug. 4	Beginning of flowering	"	9	+0,62	50,7	60,7
			12	+1,56		
			15	+0,49		
		With irrigation	9	+4,28	62,3	65,1
			12	+4,65		
			15	+3,50		
Aug. 15	Mass flowering	Without irrigation	9	+0,47	45,2	50,7
			12	—0,10		
			15	—0,54		
		With irrigation	9	+1,69	58,6	60,2
			12	+1,70		
			15	+1,12		
Aug. 18	"	Without irrigation	9	—0,33	41,2	44,0
			12	—1,35		
			15	—0,86		
		With irrigation	9	+1,62	61,6	61,5
			12	+1,30		
			15	+0,69		
Aug. 31	Mass formation of bolls	Without irriga.	9	—2,17	39,4	41,0
		With irrigation	9	—3,35	44,8	47,7
Sept. 2	"	"	9	+0,53	59,8	61,5
Sept. 3	"	"	6	—0,86	51,2	48,0
			12	—0,57		
			15	—2,17		

Note: Comma represents decimal point.

In the middle of the budding stage (July 23), when the mean moisture content in the top meter layer of soil was 61.5%, positive exudation was observed only in the early morning; during the daytime exudation was negative – an indication that irrigation was needed. In the evening 7 mm of rain fell. Despite this furrows were cut and on July 26th irrigation was performed at the rate of 400 m³ per ha. More rain (10 mm) fell in the evening of July 29th and there was a little more again on August 2nd. In the irrigation experiment abundant secretion occurred when the soil moisture was high. On August 4th positive exudation was observed throughout the entire day in the plants under irrigation as well, although the mean soil moisture, particularly in the 50 cm layer, fell appreciably. This was because there had been frequent rainfall in the preceding period, resulting in good wetting of the top 10-15 cm soil layer in which the suction of the plant root system had developed. The plants evidently used the easily available moisture from this layer first of all. Such conditions produced a favorable water regime in the treatment of the experiment without irrigation, although the mean moisture in the half meter and meter layers was comparatively low. The abundantly wetted top layer could not exert any substantial influence on the average moisture values in the half meter and meter layers. In the measurements on August 15th prolonged exudation throughout the day was observed in the plants under irrigation, along with comparatively low soil moisture. Slight rain on August 8-12 again wetted the top layer of the soil and in the irrigated treatment produced a favorable water regime for the plants. In the treatment without irrigation considerable drying of the soil was accompanied by positive exudation only in the morning. Owing to the wetting of the top layer, however, the

Table 2

Relationship between cotton exudation and soil moisture, 1956

Determination date	Stages and periods of development	Treatments	Cutting time (hr)	Exudation rate, 3 hrs. after cutting, ml	Mean soil moist. as percentage of field moist. cap. in layer, cm	
					0–50	0–100
July 20	Budding	Without irrigation	9	+0,56	54,6	57,3
			12	+0,78		
			15	+0,04		
July 26	"	"	9	+2,50	73,7	68,0
			12	+3,29		
			15	+2,66		
Aug. 6	Beginning of flowering	"	9	−1,08	46,6	49,5
			12	−1,22		
			15	−1,91		
		With irrigation	9	+2,85	74,0	68,6
			12	+4,36		
			15	+1,97		
Aug. 10	Mass flowering	Without irrigation	9	−1,94	39,4	45,2
			12	−1,42		
			15	−1,88		
		With irrigation, point 1	9	+1,67	62,2	59,5
			12	+1,54		
			15	+1,36		
		With irrigation, point 2	9	+0,92	69,7	66,1
			12	+3,62		
			15	+1,90		
Aug. 1	Mass flowering	Without irrigation	9	−0,86	36,4	46,1
			12	−1,85		
			15	−2,32		
		With irrigation, point 1	9	−0,30	55,8	59,1
			12	0,00		
			15	−0,07		
		With irrigation, point 2	9	+0,50	82,8	70,8
			12	+0,86		
			15	+2,25		
Aug. 22	Mass formation of bolls	Without irrigation	9	−2,68	30,0	33,8
			12	−2.30		
			15	−2,66		
		With irrigation, point 1	9	−2,00	42,7	47,7
			12	−3,70		
			15	−1,64		
		With irrigation, point 2	9	+1,41	60,0	55,4
			12	+0,97		
			15	+0,39		
Aug. 29	Mass formation of bolls	With irrigation, point 1	9	−1,46	57,2	55,7
			12	−2,43		
			15	−1,90		
		With irrigation, point 2	9	−2,42	52,7	48,0
			12	−2,39		
			15	−2,15		
		With irrigation, point 3	9	−0,08	67,6	68,0
			12	−0,22		
			15	−1,10		

Note: Comma represents decimal point.

change from positive to negative exudation occurred at an unusually low mean moisture value. On August 18, with the onset of soil drought in the treatment without irrigation, negative exudation was observed in all the observation periods. Nevertheless, positive exudation was observed on the same day at the most wetted point of the irrigated plot when soil moisture was 61.5% of field moisture capacity.

During the next period the weather was hot and dry. At the end of August and the beginning of September turgor losses and wilting of the leaves were observed, particularly in the non-irrigated plot. On August 31, and September 3, sudden drying out of the soil was accompanied by negative exudation in the plants of both the irrigated and non-irrigated plots. At the same time, however, positive exudation was observed in the plants at the ends of the furrows which had been most wetted during the irrigation and rain.

Similar values were obtained in 1956, too (Table 2), but again no clear quantitative relationship between the soil moisture and the cessation of positive exudation from the plants was found. On August 17, for example, when the mean soil moisture in the top meter layer was 59.1% of field moisture capacity, the moment of cessation of positive exudation was found to occur when the plants were cut at midday. On July 20, however, when the soil moisture was lower, positive exudation was observed throughout the day — again because of the high degree of wetting of the top 10-15 cm soil layer, owing to slight rainfall during the preceding period. On August 29, very slight but negative exudation was observed at one of the points in the non-irrigated area even when the soil moisture was higher (68% of field moisture capacity). On the other days when measurements were made abundant exudation was due to the high degree of wetting of the top 30-40 cm layer after slight irrigation (350-500 m³ per ha). The presence of readily available moisture in the top layer of the soil produced a favorable water regime for the plants, characterized by positive exudation even at comparatively low mean moisture values both in the meter and in the half-meter layers.

Thus far, we have been taking the calculated layer arbitrarily at 0-50 or 0-100 cm. It is quite obvious that even with a more differentiated thickness the differentiation in the calculated layer according to stages of development will be maintained.

Figure 2 shows the most typical cases of non-uniform distribution of moisture along the profile of the top meter layer at the points where exudation was determined. The same figure shows the field moisture capacity and 1.5 maximum hygroscopicity of the soil. It is quite clear that the positive exudation observed under the favorable water regime of August 17 (Table 2, point 2) was due to the presence of readily available moisture in the top 50 cm layer, although the active root layer of the soil in the cotton plantation had by this time reached a depth of 80-100 cm. On August 22 positive exudation, even at the other point, was due to the presence of readily available moisture only in a small layer of the soil at a depth of about 30 cm. At 40 cm and more the soil was very dry. Such wetting conditions along the profile of the root layer when slight irrigation had been applied destroyed the quantitative relationship between the mean moisture of the half meter and meter layers and the moment of cessation of exudation. In this instance the soil moisture at a depth of 30 cm was 68.4% of field moisture capacity and gave a more accurate indication of the water regime of the plants, corresponding to the phase of development of the cotton, than did the mean moisture of the whole calculated layer even when its depth was determined with better differentiation. On August 29, when all the readily available moisture in this layer of the soil had been exhausted too, negative exudation was observed.

The moment when exudation in the plants ceases under field conditions, does not, then

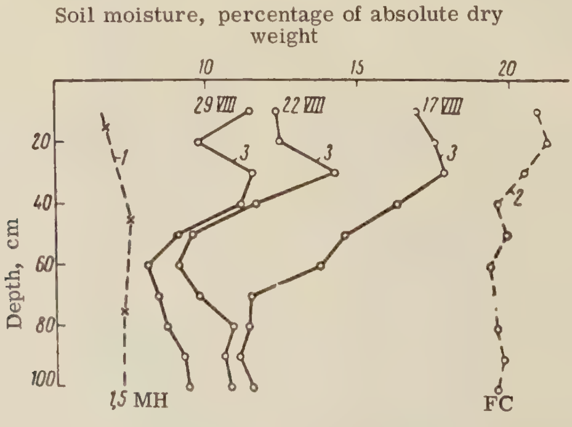

Fig. 2. - Distribution of moisture in top meter layers of soil after low rate irrigation.
1 - 1.5 maximum hygroscopicity; 2 - field moisture capacity; 3 - distribution of moisture on dates observed.

correspond to a definite and constant degree of wetting of the root layer or, as it has become accepted practice to call it, the irrigated plot or calculated soil layer. In our experiments the change from positive to negative exudation when the cotton plants were cut between 12:00 and 14:00 hours was found to occur when the mean moisture of the calculated layer lay between roughly 50%-70% of field moisture capacity, being determined by the character of the moisture distribution down the profile of the root layer. Where there was abundant wetting of the top layer with slight irrigation or after rain which had produced a favorable water regime for the plants, the moment when exudation ceased was often found to occur at lower values of mean moisture in the calculated layer. The "critical" or "moisture of retarding plant growth," as determined under field conditions from the averaged moisture of the calculated layer, was consequently not a constant. This is obviously the reason why in a number of experiments summarized by Alpat'yev (1) and others, a favorable irrigation regime was ensured by keeping the soil moisture at a lower level — 60%, or even 50% of field moisture capacity. In most cases, however, a favorable water regime for the plants is obtained when the moisture of the calculated layer before irrigation is 65%-70% of field moisture capacity. With this degree of soil wetting cotton exudation usually ceased, under field conditions, when the moisture distribution down the profile of the root layer was most normal.

At the same time, it must be noted that "critical moisture" below which plant growth starts to be suppressed, can have a constant value only when there is an even distribution of available moisture throughout the root layer, and, as Rode suggests, corresponds to the so-called "capillary rupture moisture" or is at least near to this value.

Evaluating the results of these investigations we find that they provide confirmation for the existence of a very close connection between soil moisture and plant exudation, such as Litvinov (5) had observed and evaluated in his time and on which Rode later placed great emphasis (6). After the tops of plants are removed the root system proves to be a special kind of osmometer for directly determining the availability of soil moisture to the plant under field conditions. A most important point here is that the exudation is an integral indicator of all the factors which, in whatever degree, influence the availability of soil moisture to plants. The results obtained on the example of cotton throw light on the quantitative relationship between plant exudation and soil moisture under field conditions, with allowances made for the most important water-physical constants, and give a precise value for the "critical" moisture for plants below which plant growth is suppressed and yields reduced.

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EFFECT OF CRACKS ON SOIL MOISTURE

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In dry weather cracks form in soils, particularly in clay loams and clays, accelerating moisture losses.

We observed the formation of numerous open cracks in the soil in experimental plots of barley at the Voronezh Institute of Agriculture Training Farms during the June 1956 drought and studied their effect in drill-seeded, close drill, drill-less and crossed seeded plots.

Numerous measures of the width, depth, and extent of the cracks in all these plots are shown in Table 1. The cracks were measured in meter squares marked out with frames set at a specified number of steps diagonally across the plot.

As we see, there was without a doubt a connection between the size of the cracks and the degree to which the soil was shaded by the plants, this in turn depending on the regularity of the sowing pattern.

Table 2 shows how the plot was used with

Table 1

Dimensions of soil cracks in barley seed beds, cm

Method of sowing	Mean		Mean length per m²
	Width	Depth	
Drilled	2,10	22,0	245
Close-drill	1,70	24,0	163
Crossed	1,84	20,6	140
Drill-less	1,76	20,0	120
Close drill-crossed	1,60	16,0	114
Drill-less-crossed	1,58	14,0	113

Note: Comma represents decimal point.

Table 2

Use of arable area with various methods of seeding, and standing density of 400-500 plants per m²

Methods of sowing	Percentage of area		
	With optimum plant distribution	With dense plant distribution	Not occupied by plants
Drilled	20,0	19,0	61,0
Close-drill	35,4	17,1	47,5
Crossed	35,0	19,8	45,2
Drill-less	34,7	16,6	48,7
Close drill-crossed	48,5	14,5	37,0
Drill-less-crossed	51,5	10,3	38,2

Note: Comma represents decimal point.

each of the different methods of sowing; the values were obtained by investigating the total quantity of shoots, a screen half a meter square, of 5 cm mesh, being used for the purpose.

With the drilled sowing, the area not occupied by plants made up 60% of the total. With close drill and drill-less-crossed sowing the corresponding area was 40%. The sizes of the cracks varied according to the same pattern, as can be seen from Table 1. The more uniform distribution of the plants when the crossed seeding method was used was undoubtedly a factor in keeping down the formation and extension of the cracks. The cracks formed mainly in the open parts of the sown area — between rows and in balks. There were invariably a great many fewer of them in the shaded parts.

where W is the water content in the soil in m³ per ha; H is the thickness of the soil layer, in meters; P is the bulk density of the soil; q is the soil moisture, in percentages.

While investigating the soil moisture content in the crack zone we also determined the bulk density in these places (leached clay loam chernozem). The values obtained, layer by layer, were as follows:

Depth	0-10	10-20	20-30	30-40	40-60	60-80	80-100cm
P	1.80	1.15	1.22	1.23	1.24	1.25	1.29 g/cm²

The volume of soil in the zone subject to the action of cracks is determined from the equation:

$$V = 10^4 \cdot L \cdot C \cdot H \text{ m}^3/\text{ha}, \qquad (2)$$

Table 3

Influence of soil cracks on horizontal and vertical drying of the soil

Layer, cm	Drill seeding				Close drill seeding			
	Control	30 cm	15 cm	In crack	Control	30 cm	15 cm	In crack
		From axis of crack				From axis of crack		
0—10	11,2	11,8	8,4	5,8	16,8	15,1	12,2	9,6
10—20	12,7	13,2	10,7	6,8	18,2	16,0	12,6	10,9
20—30	15,1	14,3	13,9	13,4	16,5	15,4	13,4	12,2
30—40	17,1	15,9	14,7	15,4	16,0	16,7	12,9	13,4
40—60	16,6	16,8	15,6	16,0	16,4	17,4	14,3	13,9
60—80	18,3	17,4	16,0	16,7	18,0	18,6	15,9	15,1
80—100	20,9	18,6	17,9	16,9	18,9	19,3	16,6	17,6
0—100	16,8	16,1	14,7	14,1	17,4	17,4	14,5	13,9

Note: Comma represents decimal point.

Table 3 shows the results of investigating the influence of soil cracks on the moisture content of the adjacent soil layers. The moisture samples were taken by layers to a depth of 1 meter in the cracks and alongside them at a distance of 15-30 cm.

The moisture content was determined in the second 10-day period in June at the onset of the stem extension stage. The samples were taken from cracks 20-30 cm deep and 2-3 cm wide.

It can be seen from Table 3 that the effect of the cracks on soil moisture content is felt in some measure throughout the top meter layer, but is particularly noticeable in the soil layers adjacent to the cracks and is most marked in the topmost horizon. The influence of a crack ceases at a distance of approximately 30 cm from its longitudinal axis.

We shall calculate the moisture loss from 1 hectare of drill seeded land with soil cracks. The moisture content is determined from the control moisture indices (crack-free areas), from the well known formula

$$W = 100 \cdot H \cdot P \cdot q \text{ m}^3/\text{ha}, \qquad (1)$$

where V is the volume in m³ of soil subject to the action of cracks over an area of 1 ha; 10^4 is the area of 1 ha in m²; L is the mean aggregate length of the cracks in m/m²; C is the width, in m, of the area subject to the effect of cracks; H is the height, in m of the soil horizon on which the moisture content and losses are calculated.

Since the moisture samples were collected from cracks and at distances of 15 and 30 cm from the cracks, in our case C = 0.3 m (15 cm to the left and 15 cm to the right of the crack); the mean soil moisture content for the first area, 15 x 2 = 30 cm wide, is:

$$q_n = \frac{q_0+q_1}{2}\ \% \qquad (3)$$

and for the second area, (30-15)2 = 30 cm,

$$q_b = \frac{q_1+q_2}{2}\ \%, \qquad (4)$$

where q_0 is the moisture percentage in the crack, q_1 the moisture at a distance of 15 cm from the axis of the crack and q_2 the moisture at a distance of 30 cm from the axis of the crack.

Using the values in Table 1 and formula (2) we find that the volume of soil subject to the action of cracks in drill sowing is

$$v = 10^4 \cdot 2.45 \cdot 0.3 \cdot H = 7350 \cdot H \text{ m}^3/\text{ha} \qquad (5)$$

Hence the moisture losses from the soil as a result of cracks in drill seeded plots is determined from the formula

$$W_n = V \cdot P \cdot \Delta q \text{ m}^3/\text{ha}. \qquad (6)$$

Here W_n is the moisture losses in m^3 per ha; P is the bulk density of the soil; Δq is the difference, in fractions of a unit, between the moisture of the soil horizon taken and the mean moisture in the given area; that is,

$$\Delta q = q - q_n; \ \Delta q = q - q_b. \qquad (7)$$

Using the values from Table 3 and the formulae given above we find the moisture losses from the soil from the appearance of cracks (Table 4).

Table 4

Moisture losses in soil due to the presence of cracks; drill seeded barley

Layers, m	Moisture contents, m³/ha	Moisture losses from cracks, m³/ha			Moisture losses as percentage of moisture contents
		Zone 1	Zone 2	Total	
0—0,1	121	32,6	8,8	41,4	34,2
0,1—0,2	146	33,0	6,8	39,8	27,3
0,2—0,3	184	12,5	9,0	21,5	11,7
0,3—0,4	210	19,0	16,4	35,4	16,8
0,4—0,6	412	14,6	7,4	22,0	5,3
0,6—0,8	458	34,8	29,4	64,2	14,0
0,8—1,0	540	66,5	51,2	117,7	21,8
0—1,0	2071	213	129	342	16,5

Note: Comma represents decimal point.

The cracks removed 16.5% of the moisture from the top meter of soil, the maximum relative loss occurring in the top horizons, where most of the plant roots are situated. The corresponding moisture loss in the close drill plot amounted to 13%.

As a proportion of the physiologically useful moisture content (above wilting) this percentage represents roughly a third in the drill seeded plot and about a fourth in the close drilled plot.

As we see, the cracks represent a powerful pump, drawing a large amount of the moisture from the soil that is necessary to plants. An important aim of management is to cover this source of loss.

A good way of counteracting cracks is to destroy the crust under growing crops with harrows, rotary hoes and ribbed rollers. A method which has long been used in advanced agricultural practice in early spring single or double trace harrowing of winter crops; this can be conveniently combined with the addition of mineral supplements.

A certain amount of weeding is done when the crust is broken down, with the result that a loose top layer is formed; this militates against cracking and in general reduces moisture evaporation from the soil.

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GAMMA RAY METHOD OF DETERMINING MOISTURE N COARSE FRAGMENTARY SOILS

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The literature contains many papers on methods of determining the moisture content of soils and rocks by the gamma ray method (1, 2, 4). Various calculation formulae are suggested. Ratios of the mass coefficient attenuation of gamma ray (for a wide beam) to the density and distance between the source of radiation and the counter have been obtained (2, 4). It is noteworthy however, that there is still no sufficiently reliable method of determining moisture of soil and rocks under field conditions. In this paper we discuss one of the possible ways in which a broad beam of gamma rays could be used for this purpose. The method of measurement is based on the experimentally established fact that the effective mass attenuation coefficient of a broad beam is independent of the soil moisture. Here it must be noted that both in laboratory experiments and in observations of moisture variation under natural conditions the bulk density of the skeleton soil remained constant.

The methodology of moisture measurement is simplified appreciably if the observations are made at permanent plots. Two borings were drilled in the experimental area. The source-to-counter distance was not varied throughout the observation period, so there was no necessity to allow for variation of the gamma ray attenuation-coefficient with distance.

An almost parallel beam of gamma-quanta, its angle of half solution being 1-2°, was used in the experiment. The counter was placed in a lead housing with an aperture for the emergence of the gamma-quanta beam. The source (Co^{60}, activity about 20 microcuries) was placed in a lead container with an aperture for collination of the beam (Fig. 1).

It was established that the attenuation of the gamma radiation in a moist soil (sand) could be well described by the following simple formula

$$N=N_0e^{-\mu_{eff}\rho_w x}, \qquad (1)$$

where μ_{eff} is some effective mass coefficient of attenuation after allowance has been made for secondary radiation; ρ_w is the bulk density of the moist soil and x is the distance between the borings.

In order to approximate the laboratory experiments as nearly as possible to natural conditions they were performed in a large trough measuring 150 x 75 x 75 cm³. The borings were modelled in the tray by means of iron tubes 89 mm in diameter set 50-60 cm apart. The experiment was controlled in a thermostat drier.

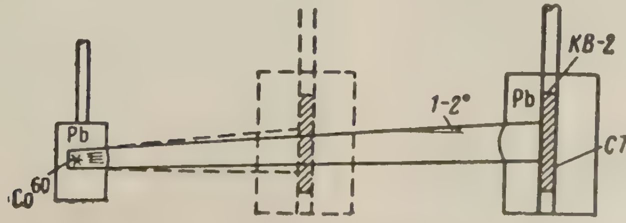
The experiments showed that over a fairly wide range of moisture variation (0%-20%) the effective mass attenuation coefficient did not depend on moisture (Table 1).

The independence of μ_{eff} on moisture content made it possible to follow its variation under field conditions by proceeding from formula (1).

If there is no change in the bulk density of the ground skeleton in the process of measurement we can in fact write the following formula for two values of the moisture content, w_1 and w_i:

$$N_1=N_0e^{-\mu_{eff}\rho_{sk}(1+wi)x},\ N_i=N_0e^{-\mu_{eff}\rho_{sk}(1+w_i)x}$$

from which it follows that



Geometry of the experiments

$$w_i = \frac{\ln \frac{N_1}{N_i}}{\mu_{eff}\,\rho_{sk} x} + w_1, \; (i=2, 3, \ldots) \qquad (2)$$

It can be seen from formula (2) that once we have determined the value of w_1 by thermostatic drying and the pulse count rate N_1 corresponding to it, we can perform the observations on moisture contents.

Table 1

Moisture-content values obtained in the thermostatic drier

%	μ_{eff}	%	μ_{eff}
1,7	0,05106	9,1	0,05049
3,4	0,04916	10,0	0,04785
4,3	0,04911	10,5	0,04912
5,5	0,04948	11,0	0,05035
6,0	0,04953	13,2	0,04960
7,4	0,04864	14,2	0,04849
7,5	9,04954	14,3	0,04994
8,0	0,04925	15,4	0,04944
8,8	0,04991		

Note: Comma represents decimal point.

To verify the propositions set out, observations on the change of the diurnal course of moisture in the subsoil layer were made in the summer of 1959 at the high mountain station of Suntar Khayat, which was working on the third IGY programme. The observations were made by 10 cm layers to a depth of 60 cm. Other methods of observation on moisture charge were not used at Suntar Khayat, since the parent material on which the observations had to be made consisted of coarse fragmentary stones. Therefore, the very concept of moisture content could be used only in relation to a fairly considerable volume of parent material. The moisture values obtained gravimetrically might therefore differ substantially from one point to another and only the averaged values would be reliable. This meant that gamma radiation was the only method that could be used to observe the variation of subsoil moisture in the 60 cm layer.

A B-2 apparatus was used to obtain accuracy of measurement in the pulse count registration. The filament valves of this apparatus were fed from accumulators and an anode voltage of 300 c was taken from a converter working from a 24 V accumulator. Current was supplied to the counter from a GB-400 discharge battery. This battery maintains a strictly constant voltage over a long period and so gives an advantage in regard to accuracy of measurement.

To perform the observations at the Suntar-Khayat station it was necessary to determine the effective mass attenuation coefficient for the given type of subsoils and to discover the relationship between this coefficient and the moisture content. This was done by the following method.

An iron box, measuring 51.5 x 22 x 28.2 cm was made and filled with soil material of varying degrees of moisture. The bulk density of the ground skeleton remained strictly constant. The box was then put between the source and the counter and the μ_{eff} for various ρ_{sk} and moisture content w was determined. Table 2 shows that μ_{eff} remained practically constant over a wide range of moisture content variation (from 0-27%).

Table 2

Moisture content, %

Thermostatic drying	μ_{eff}	As calculated from formula (2)
0,0	0,0469	0,0
1,5	0,0467	1,4
2,1	0,0470	1,8
2,2	0,0462	2,4
27,0	0,0462	26,8

Note: Comma represents decimal point.

The mean value of the effective mass relaxation coefficient under our conditions proved to be 0.0466. For convenience, Table 2 shows the moisture values as determined gravimetrically on the left hand side and as determined from formula (2) on the right hand side.

Once μ_{eff} had been found for the Suntar-Khayat rocks it became possible to determine the compaction of the skeleton soil between the borings where it was proposed to carry out the observations on moisture contents. For this purpose the space between the borings was filled with dried soil material and the value of ρ_{sk} in the different horizons was determined from the formula

$$\rho_{sk} = \frac{\ln \frac{N_0}{N}}{\mu_{eff} x} \qquad (3)$$

(x = 51.5 cm).

The experimental boring was then left to saturate. Saturation was fairly rapid, as there was heavy rainfall during this period.

Table 3 shows some results of the observations on diurnal moisture-content change at the Suntar-Khayat station. The values obtained by the thermostat drying, relating to the surface layer, are compared with those obtained by the gamma ray, relating to a layer at a depth of about 10 cm. The explanation of certain discrepancies in the values is that the samples used for the gravimetric method were taken directly from the ground surface (Table 3).

Formula (2) was used to process the results, with $w_1 = 0$. In most cases the values obtained by each method were found to correspond

Table 3

Soil moisture values obtained by two methods, %

Date of observations in August	Hour of observation	Thermostatic drying of surface layer	Gamma ray method on layer about 10 cm deep
5	7	0,7	1,3
	13	0,5	0,5
	19	3,3	1,7
6	7	0,5	0,5
	13	0,2	1,0
	19	0,6	1,0
7	7	0,2	0,8
	13	0,2	0,8
	19	0,3	1,0
11	7	0,3	0,3
	13	0,1	0,5
	19	0,2	0.3
13	7	0,2	0,5
	19	0,1	0,1
14	7	0.2	0,1
	19	0,2	0,1
15	7	0,0	0,1
	19	1,3	0,5

Note: Comma represents decimal point.

The results were also found to correlate with meteorological conditions. On August 5, for example, rain fell; the moisture content of the surface layer was 3.3%. It was not possible for the moisture to soak through completely to a depth of 10 cm by the time the count was taken, but even at that depth the moisture content did rise to 1.7%. On August 15 rain again fell, with the same effect.

Despite the low moisture values observed at Suntar-Khayat, the gamma ray method gives a fairly high degree of accuracy owing to the coarse texture of the rocks. The relative possibility of error in determining the moisture content can be found from the following ratios:

$$\frac{w}{w}\Big| = 2\Big|\frac{\frac{\Delta N}{N}}{\log N}\Big| + \Big|\frac{\Delta\mu_{eff}}{\mu_{eff}}\Big| + \Big|\frac{\Delta\rho_{sk}}{\rho_{sk}}\Big| + \Big|\frac{\Delta x}{x}\Big| \quad (4)$$

Expressed as a percentage, the margin of error does not exceed ±0.4%. The low probability of error in measurement given by the method under discussion made it possible to detect the presence of condensation moisture in the top layers of the ground on days when there was no precipitation and the top layer had dried out sufficiently. This was corroborated from visual observations.

In conclusion, we may say that under permanent field conditions, where it is possible to determine the compaction of the skeleton soil, ρ_{sk}, and be sure that it has not changed during the observations, the use of a wide gamma ray beam is a fairly accurate and convenient method of performing observations on moisture change in soils and parent material.

Received February 2, 1960

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CHRONICLE

FIRST CONFERENCE OF SIBERIAN SOIL SCIENTISTS

A conference of Siberian soil scientists, convened by the Krasnoyarsk division of the All-Union Society of Soil Scientists (VOP) and the Institute of Forests and Timber of the Siberian division of the USSR Academy of Sciences, was held March 10 to 14, 1961.

The conference was attended by soil scientists from the Omsk, Novosibirsk, Kemerov, Tomsk, Irkutsk, Chita, and Amur Oblasts' and from the Buryat, Yakut, Altay, and Krasnoyarsk krays. There were 128 participants in all.

The All-Union Society of Soil Scientists was represented by its Vice President, Professor S. V. Zonn, Professor K. P. Gorshenin, corresponding member of the All-Union Institute of Scientific Research on Agriculture, and others.

Forty-four papers were read and discussed. The subjects covered included the genetic characteristics and classification of soils in different regions; the forest soils of Siberia; map-making; the establishment of site quality indices for soils in the Tomsk Oblast'; soil physics; water, nutrient, and microbiological regimes; freezing processes; bog soils and their melioration; saline soils and their reclamation; wind erosion; continuous-cultivated soils; the micro-elements of soils and their methods of determination; agricultural chemistry; the role of earthworms and root systems; and information on the work of local societies of soil scientists.

The conference laid down lines for the further improvement of soil and agricultural chemical research, brought out the importance of large scale soil maps of collective and state farms and the necessity for a close tie up between science and production, and elected a committee to coordinate all soil and agricultural chemical work in Siberia and bring Siberian soil scientists into closer contact with one another.

In its resolution, the conference:

1. Endorsed the initiative of the Krasnoyarsk division of the VOP and of the Institute of Forests and Timber of the Siberian division of the USSR Academy of Sciences in calling a scientific conference of Siberian soil scientists.

2. Considered that in addition to soil mapping, the following tasks were of immediate importance for Siberia: theoretical and practical research on water and wind erosion; the study of regional peculiarities of soils from the standpoint of genetics and agricultural production; the diagnosing of regional soil requirements in fertilizers, in conjunction with the study of the micro-elements of soils, irrigation and drainage melioration; and the reclamation and continuous cultivation of saline lands.

3. Considered it essential to encourage local VOP branches to push ahead as rapidly as possible with large-scale surveys of state and collective farms and to improve the quality of all their work.

Directed the attention of the Ministry of Agriculture to the necessity for more thorough study of the physical and chemical properties of Siberian soils and of providing modern instruments and equipment for soil and agricultural chemical laboratories.

4. Resolved to enhance the value of pedalogical research material by publicizing, through pamphlets and word of mouth propaganda, knowledge of local soils and their properties, and by stimulating a more intelligent use of soil maps and other research material.

5. Decided to discuss with the USSR Ministry of Agriculture and the Ministry of Higher and Secondary Education the question of drastically expanding the training of soil scientists, both at universities and agricultural institutes of higher education and through training courses for agronomists, foresters, melioration officers, and rural school teachers, and drew particular attention to the fact that with the exception of the University of Moscow not a single educational establishment was training soil scientists for reclamation work.

6. Stated that the territorial and provincial divisions of the VOP must systematically help the departments of soil conservation and land survey attached to the Boards of Agriculture to take an active part in the work of selecting experimental farms in which natural conditions were typical, and help the experts at these farms to organize the work of soil and agricultural chemical laboratories and so forth.

7. Decided to promote more work on the study of soils in the forest regions of Siberia and to recommend that soil scientists take an active part in working out the scientific foundations for forestry in Siberia.

8. Drew the attention of the governing body of the Siberian division of the USSR Academy of Sciences and also of the Ministry of Agriculture of the RSFSR to the necessity of organizing in Siberia an extensive network of soil stations for advanced research on the genetic and productive properties of Siberian soils used in agriculture and forestry.

9. Drew the attention of the biological sciences division of the USSR Academy of Sciences to the fact that for two years there had been no session of the interdepartmental committee on soil classification in the Soviet Union, and considered it opportune to work out the problems involved in classifying soils by regions.

10. Considered it opportune to set up in Siberia a coordinating committee consisting of K. P. Gorshenin, N. D. Gradoboyev, R. V. Kovalev, S. A. Kolyago, O. V. Makeyev, B. V. Nadezhdin, N. V. Orlovskiy, M. A. Pikalov, and N. F. Tynmentsev, and provided that the committee's program of work should include scientific and scientific production conferences, conferences on methods, and advisory meetings with local divisions of the VOP on aspects of soil science presenting problems, and also exchange of information on work.

Considered it advisable in order to make the work of the coordinating committee explicit, that its functions be distributed among its members as follows:

a) Novosibirsk division of the VOP — questions of medium and small-scale map making, programs and methods of station research;

b) Krasnoyarsk division of the VOP — soil erosion and melioration, research on Siberian soils from the standpoint of forest management and agricultural chemistry;

c) Omsk division of the VOP — large-scale soil mapping and the reclamation of solonetz soils;

d) Buryat division of the VOP — study of microelements and the natural radio-activity of soils;

e) Tomsk division of the VOP — questions of establishing site quality indices for soils.

11. Instructed the coordinating committee of the Siberian division of the VOP to carry out the organizational and scientific preparation of documents and papers by Siberian soil scientists for the second delegate conference of the VOP;

12. Requested the Institute of Forests and Timber of the Siberian division of the USSR Academy of Sciences to publish the conference material.

13. In view of the rate of reclamation of vast land reserves in Siberia and the necessity of all-round study of the soil, requested the Presidium of the Siberian division of the USSR Academy of Sciences to inaugurate a journal entitled "Soils of Siberia."

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I. I. Smol'yaninov

SCIENTIFIC CONFERENCE ON ESTONIAN SOILS

The Estonian branch of the All-Union Society of Soil Scientists, the Estonian Agricultural Academy, and the Society of Naturalists attached to the Estonian Academy of Sciences held a scientific conference on Estonian soils at Tartu from March 28, to April 1, 1961. During the five days of the conference 55 scientific papers and communications were read and discussed. The topics covered included large-scale mapping, the genesis, geography, and properties of soils, land evaluation, the determination of soil requirements in fertilizers and liming, and the practical use of soil and agricultural chemical research material.

The conference was attended by representatives of 57 institutions. Average attendance at each of the eight sessions was 140 people. In addition to Estonian soil scientists, agricultural chemists, and agricultural workers, representatives from Moscow, Leningrad, Latvia, Byelorussia, Georgia, the Karelo-Finnish ASSR, and the Novgorod and Pskovsk provinces took part.

Professor Yu. A. Liverovskiy dealt (in his paper) with the problems of classifying and mapping soils in connection with large-scale research in a non-chernozem zone. Problems relating to the genesis of podzolic and sod-podzolic soils were discussed in a paper by V. V. Ponomareva. The main paper on large-scale soil mapping in Estonia was read by L. Yu. Reyntam and I. Rooma, and A. I. Lillema, R. K. Pant and R. P. Kask reported on land evaluation. E. I. Raudviali spoke on the question of streamlining the work of total chemical analysis in the laboratory, and A. P. Piko on the use of information provided by the agricultural chemical service. A film on the work of the Kuuzik agricultural chemical laboratory was shown. Reports by K. K. Brivkalna and I. I. Vaitekunas dealt with work on large-scale soil mapping and land evaluation in Latvia and Lithuania, and the results of agricultural chemical research on the soils of these Republics were presented by A. Svedas and A. P. Zemit.

G. I. Grigor'yev, A. S. Konovalova, and N. D. Pustovoytov, members of the scientific staff of the Dokuchayev Soil Institute, acquainted the conference with the results of their research on the properties of virgin and continuously cultivated sod-podzolic soils in Estonia. A paper by R. A. Sepp dealt with the first attempt at mapping the forest soils of Estonia and another, by A. V. Raukas, described in detail the characteristics of moraines as soil-forming parent material. Several papers on the different properties of Estonian soils were heard (L. U. Reyntam, H. E. Kendra, E. J. Kitse, A. O. Kongo, A. I. Lillema, R. A. Sepp, I. P. Rooma, K. M. Pork, and others). Papers by O. O. Ryys and V. P. Lepasepp dealt with methodological problems in mapping the land reserves.

A first summary on the comparative productivity of soils, based on actual data from particular farms, was given in papers by R. R. Kokka and J. P. Torima; data on the use of soil research in organizing land areas and solving problems of agricultural economy were contained in reports by L. H. Pal'ma and L. R. Lilover. An experiment in the practical use of soil research material was described in papers by the agronomists L. P. Vaaks, J. A. Peets, and V. Nestor. Papers on aspects of agricultural chemical soil research, fertilizers, liming, and agricultural techniques were read by Professors O. G. Hallik, H. A. Kjarblan, L. G. Kevvay, V. M. Waller, E. M. Turbas, H. K. Michelson, R. Kaljmet, J. M. Reemann, and others.

The conference took place in an atmosphere of keen creative endeavor and the guests noted that Estonian soil scientists and agricultural chemists were in close touch with agricultural practice and with related sciences (geology, geobotany and so forth), and that joint research was being performed.

The resolutions adopted mentioned the problems ahead in regard to large-scale soil mapping, land evaluation, the large-scale investigation of soil requirements in fertilizers and lime, and the study of various soil properties. It was decided to hold further annual conferences in Estonia, Latvia, Lithuania, and Byelorussia in turn. The branches of the VOP in each of the Republics were to set up an inter-Republic office for coordinating soil and agricultural chemical research. It was decided that there should be inter-republic exchanges of soil scientists and agricultural chemists. It was proposed that the papers and communications presented at the conference be published in the form of a collection.

L. Yu. Reyntam

AIBS Russian Monograph Translations

The AIBS is in the process of expanding its Russian Translations Program extensively. Funds to subsidize translation and publication of important Russian literature in biology have been obtained from the National Science Foundation, as part of a larger program to encourage the exchange of scientific information between the two countries. The following monographs have been published:

Origins of Angiospermous Plants. *By A. L. Takhtajan*
Edited by G. Ledyard Stebbins. Translated by Olga H. Gankin
68 pp. [13 illustrations] 8½ x 10¾. $3.00, individuals and industrial libraries (U.S. & Canada); $2.00, AIBS members and all other libraries; $.50 additional, foreign.

Essays on the Evolutionary Morphology of Plants. *By A. L. Takhtajan*
Edited by G. Ledyard Stebbins. Translated by Olga H. Gankin
144 pp. [32 illustrations] 8½ x 10¾. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Problems in the Classification of Antagonists of Actinomycetes. *By G. F. Gause*
Edited by David Gottlieb. Translated by Fritz Danga
165 pp. [18 illustrations] 7 x 10. $5.00, individuals and industrial libraries (U.S. & Canada); $4.00, AIBS members and all other libraries; $.50, additional, foreign.

Arachnida. Vol. IV, No. 2. Fauna of the U.S.S.R. *By B. I. Pomerantzev*
Edited by George Anastos. Translated by Alena Elbl.
199 pp. [638 illustrations] 7 x 10. $10.00, individuals and industrial libraries (U.S. & Canada); $9.00, AIBS members and all other libraries; $1.00, additional, foreign.

Arachnoidea. Vol. VI, No. 1. Fauna of the U.S.S.R. *By A. A. Zachvatkin*
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